THE
GEOLOGICAL MAGAZINE
VOLUME LXVI.

No. I.—JANUARY, 1929.

ORIGINAL ARTICLES.

Notes on the Graptolite Faunas of the Upper Ordovician and Lower Silurian.

By K. A. Davies.

WORK by the author on the rocks of the Upper Ordovician and Lower Silurian in Central Wales has led to a comparison with deposits of similar horizons in other areas. Several points of interest have arisen out of the investigation and may be of value in delimiting the zones of the Upper Ordovician and also in indicating the best workable definition of the base for the Silurian.

The work has been done under the supervision of Dr. Elles and to her I owe my thanks for many suggestions and a good deal of information. Professor Marr and Mr. King have also given me a great deal of help with regard to the collecting of the specimens.

The examination of these beds was undertaken with a view to (1) determining the exact vertical distribution of the graptolites, (2) a comparison between the faunas at the several horizons in the Moffat and other areas, (3) a study of the characteristic assemblages at these different levels, (4) the bearing of the faunas upon present stratigraphical nomenclature. Only the zones from that of *Pleurograptus linearis* to that of *Orthograptus vesiculosus* have been examined and I first propose to discuss several new species and also some special features in several well-known forms found at these horizons.

I. Palaeontological Notes.

Mesograptus cf. *modestus*. (Fig. 1.)

Only one incomplete specimen obtained but in a good state of preservation. Rhabdosome about 1 cm. in length, widening very gradually for the greater part of its length. Sicula not seen. Thecae twelve or thirteen in 10 mm.; sigmoid curvature pronounced; overlapping one-third to one-half their length. Apertural margins undulate and everted.

Description.—The rhabdosome is somewhat of the size of *Mesograptus modestus* var. *diminutus* and its several features are closely comparable with that form. Its distinction from *Mesograptus multidens*[1] lies in the slightly tapering nature of its polypary and the general form of the thecae.

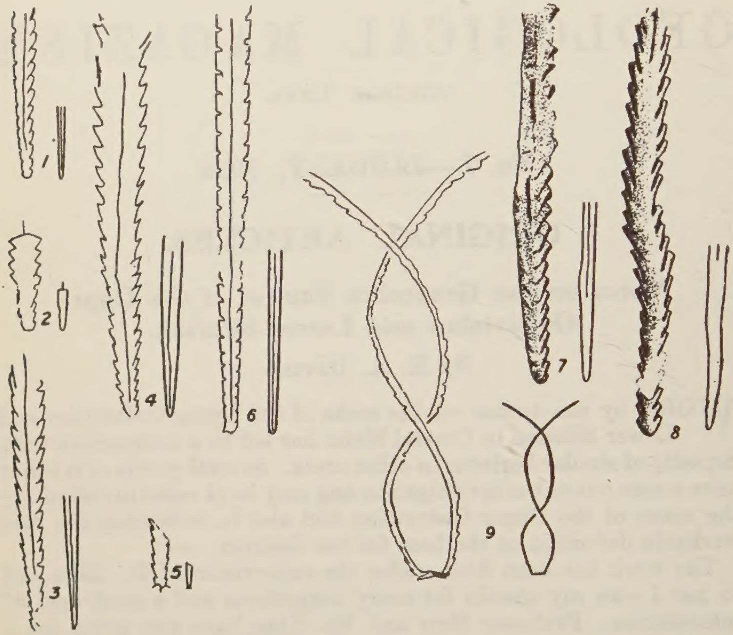


Fig. 1.—*Mesograptus* sp. Obverse view. × 2¼ (and natural size). Zone of *Dicellograptus complanatus*. Dobb's Linn, Moffat.

Fig. 2.—*Mesograptus* sp. × 2¼ (and natural size). Zone of *Pleurograptus linearis*. Dobb's Linn, Moffat.

Fig. 3.—*Orthograptus fastigatus* sp. nov. Paratype. × 2¼ (and natural size). Zone of *Dicellograptus anceps*. Dobb's Linn, Moffat.

Fig. 4.—*Orthograptus fastigatus* sp. nov. Holotype. × 2¼ (and natural size). Zone of *Dicellograptus anceps*. Dobb's Linn, Moffat.

Fig. 5.—*Orthograptus fastigatus* sp. nov. Paratype, showing spines. × 2¼ (and natural size). Zone of *Dicellograptus anceps*. Dobb's Linn, Moffat.

Fig. 6.—*Mesograptus modestus* var. *intensus* nov. Holotype. × 2¼ (and natural size). Zone of *Dicellograptus anceps*. Dobb's Linn, Moffat.

Fig. 7.—*Orthograptus truncatus* mut. *ashgillensis* nov. Holotype. × 2¼ (and natural size). *Staurocephalus* Beds. R. Rawthey, Cautley.

Fig. 8.—*Orthograptus truncatus* mut. *corrisensis* nov. Holotype. Lower portion obverse view, upper obverse. × 2¼ (and natural size). Red Vein, Corris, N. Wales.

Fig. 9.—*Dicellograptus complanatus* var. *complexus* nov. × 2¼ (and natural size). Zone of *Dicellograptus anceps*. Dobb's Linn, Moffat.

---

[1] *Monograph of British Graptolites*, p. 261.

Horizon and Localities.—Zone of *Dicellograptus complanatus* (U. Hartfell). South Scotland, Moffat, Dobb's Linn.

Mesograptus sp., cf. *Diplograptus pristis* Hisinger. (Fig. 2.)

Rhabdosome short and squat, apparently rarely attaining a length of 1 cm. Maximum breadth 2 to 2½ mm. attained by abrupt widening in proximal portion. Thecae about 14 to 1 cm. with undulate everted apertures especially in the distal portion. Lateral spines, though rarely preserved, present.

Description.—This form is typically restricted in the number of its thecae, being relatively stout. In the proximal portion, at least, it bears a close resemblance to *Mesograptus modestus* [1] except in the possession of spines, but is more of the type of *Mesograptus multidens* [2] in the nature of its everted distal thecae. The projection of the nema beyond the proximal portion is also typical of these specimens. I have refrained from naming this type owing to the lack of good supplementary examples, there being apparently some variation within those in my possession. It would appear, too, that they may represent only the proximal portions of larger specimens. The whole appearance is suggestive of the *Diplograptus pristis* of Hisinger but further specimens are needed in order to show whether these graptolites are identical.

Horizon and Localities.—Zone of *Pleurograptus linearis* (top band) (U. Hartfell) Dobb's Linn, Moffat, South Scotland.

Dicellograptus complanatus var. *complexus* nov. (Fig. 9.)

Stipes about 2 cm. in length and similar to those of *Dicellograptus complanatus* [3]; intertwined twice at more or less regular intervals. Thecae of *Dicellograptus complanatus* type.

Description.—The stipes are here typically intertwined. This variety occurs with specimens of *Dicellograptus complanatus* var. *ornatus*, which bears stout spines. The stipes are even more slender than those of the typical *Dicellograptus complanatus*, being less than 5 mm. across at the origin and less than 1 mm. at the widest part. One specimen, however, has been obtained of somewhat stouter proportions.

The sicula is similar to that of *Dicellograptus complanatus*, but is rarely preserved, whilst growth is attained as in the earlier type. Th 1^1 and th 1^2 grow off with a slight inclination downwards producing spines below the apertures. Th 2^1 and 2^2 grow horizontally for the greater part of their length, giving the rhabdosome a pronounced square axil. The ventral walls of the thecae are straight and parallel to the dorsal. Their apertures when crushed exhibit the slight rim or collar which is typical of *Dicellograptus complanatus*.

---

[1] Ibid., p. 263.

[2] Ibid., p. 261.

[3] *Monograph of British Graptolites*, p. 139.

Affinities.—Dicellograptus complanatus var. *complexus* is easily distinguishable from most *Dicellograpti* by the form of the rhabdosome, and from those like *Dicellograptus intortus, Dicellograptus caduceus* by the character of its thecae.

Horizon and Localities.—Upper Hartfell (zone of *Dicellograptus anceps*), South Scotland, Dobb's Linn, and Black Grain.

Associates.—Is a rather rare fossil occurring with *Dicellograptus anceps, Orthograptus fastigatus, Climacograptus scalaris* var. *miserablis, Climacograptus supernus*, etc.

Orthograptus fastigatus sp. nov. (Figs. 3, 4, and 5.)

Polypary 3½ cm. in length with maximum breadth of about 2½ mm.; tapering for greater part of its length. Sicula rather small. Virgella and lateral spines conspicuous. Septum apparently complete. Thecae 14 or 15 to 10 mm. overlapping one-third to one-half of their length. Apertural margins undulate and introverted.

Description.—The rhabdosome varies somewhat in size, smaller varieties than that described being present. All, however, possess the very characteristic tapering. The sicula has a length of about 1 mm. and reaches to the level of th 1^2. Th 1^1 commences some distance above the aperture and grows almost immediately upward and outward giving off a spine at a point some distance above the turn. Th 1^2 grows at first obliquely across the sicula and then directly upward, giving off a spine at the point where upward growth commences.

In profile when crushed the thecae have the typical characters of the *Orthograpti* especially in the distal portion of the rhabdosome. The proximal thecae, however, have a more pronounced curvature of the ventral wall. In most cases there seems to be an apparent deep excavation of this apertural margin, the outer edge being raised above the rest so that in crushing this is drawn out into a long denticle. The nema is rarely, if ever, seen to project beyond the distal end of the rhabdosome.

Affinities.—In the character of its distal thecae *Orthograptus fastigatus* is somewhat comparable with *Orthograptus calcaratus*, although the apertures are somewhat more introverted than in the latter. It is, however, easily distinguishable by the character of the proximal portion, its smaller form, and its typical tapering rhabdosome.

Horizon and Localities.—U. Hartfell, zone of *Dicellograptus anceps*. Scotland—Moffat, Dobb's Linn, and Black Grain.

Associates.—Orthograptus fastigatus occurs in swarms throughout the zone of *Dicellograptus anceps* in the Moffat area and is commonly associated with the zone fossil *Orthograptus truncatus* var. *abbreviatus, Climacograptus scalaris* var. *miserablis, Climacograptus supernus, Dicellograptus complanatus* var. *ornatus*, and *Dicellograptus complanatus* var. *complexus*.

Mesograptus modestus var. *intensus* nov. (Fig. 6.)

Rhabdosome over 2·5 cm. in length with maximum breadth of 2 mm., sides sub-parallel and tapering only in extreme proximal portion. Virgella conspicuous with spines or flange occasionally developed from basal thecae. About 11 thecae to 10 mm. and of *Mesograptus modestus* type.

Description.—This form is very similar to *Mesograptus modestus*, but possesses a distinctly narrower rhabdosome which is yet longer than that of the variety *diminutus*. Spines are sometimes produced from the basal thecae, whilst the virgella, although short, is prominently displayed. The sicula and thecae are very similar to those in *Mesograptus modestus* (s.s.).

Affinities.—*Mesograptus modestus* var. *intensus* may be distinguished from *Mesograptus modestus* by its narrower form and from var. *diminutus* by its longer rhabdosome and the occasional presence of appendages upon the basal thecae.

Horizon and Localities.—Upper Hartfell (zone of *Dicellograptus anceps*), South Scotland, Dobb's Linn, and Black Grain.

Associates.—Is a rather rare fossil occurring with *Dicellograptus anceps*, *Orthograptus fastigatus*, *Climacograptus scalaris* var. *miserablis*, *Climacograptus supernus*, etc.

Orthograptus aff. *truncatus* Lapworth. (Figs. 7 and 8.)

Within the Bala rocks of Scotland, Wales, and the north of England mutations of *Orthograptus truncatus* occur in abundance, and although in most cases they are preserved as mere films upon the rock surface, specimens in full relief may be obtained from Cautley, Corris, and Llangranog (Cardiganshire).

In the past these graptolites have been identified as *Orthograptus truncatus* var. *abbreviatus* Elles and Wood,[1] although a great deal of variation is to be noticed even within the specimens from one horizon.

Mode of Growth (Fig. 8*a*).—In the first place a downward growth commences at an infold of the sicula wall at a position somewhat nearer the mouth than the apex of the embryonic portion. This downward growing portion then gives rise to th 1^1 and th 1^2, the growth of the former before it turns upwards lying below the aperture of the sicula. The structure seen at the base when sections are made vary somewhat in their time of incoming, but in most cases they occur as in the diagram given. Th 1^2 becomes walled off at its dorsal portion before the sicula loses its position at the side of the rhabdosome whilst a spiral growth round the sicula occurs as th 1^1 dies out. Subsequently th 1^2 becomes released from contact with the sicula and itself comes to an end. Th 2^1 and 2^2 then appear in turn, that is, after those immediately beneath them have died out, and this procedure is maintained throughout the rhabdosome.

---

[1] *Monograph of British Graptolites*, p. 235.

FIG. 8A

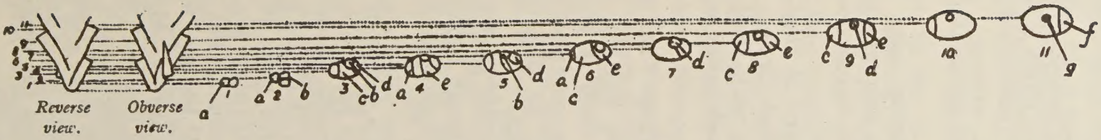


FIG. 8A.—Sections showing growth in *Orthograptus* aff. *truncatus* Lapworth. × 6¼. *a* = upward growth of th 1[1]; *b* = downward growth of th 1[1]; *c* = th 2[1]; *d* = sicula; *e* = th 1[2]; *f* = th 2[2]; *g* = nema; *s* = septum.

FIG. 11A

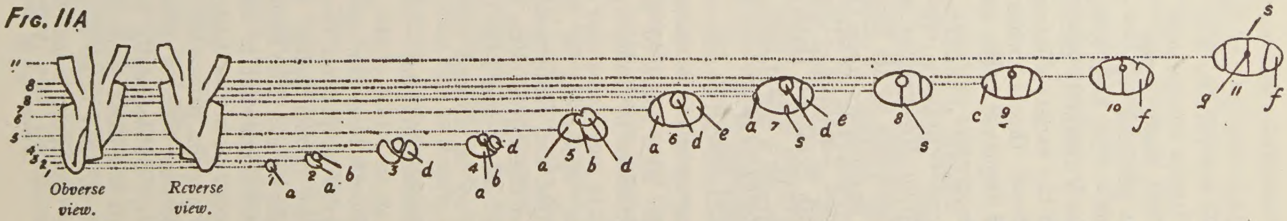


FIG. 11A.—Sections showing growth in *Glyptograptus* aff. *persculptus*. × 9. *a* = upward growth of th 1[1]; *b* = downward growth of th 1[1]; *c* = th 2[1]; *d* = sicula; *e* = th 1[2]; *f* = th 2[2]; *g* = nema; *s* = septum.

Growth in a similar form has been described by Kraft, who has called this particular graptolite *Diplograptus gracilis* F. Roemer.[1]

Character of the Rhabdosome.—The first feature of note within the specimens collected is that when uncrushed the cross-section is always elliptical. This is in contradistinction to the generic character (*Orthograptus*)[2] as stated by Lapworth, who says that *Orthograptus* possesses an almost quadrangular cross-section whilst *Orthograptus truncatus* itself is described as having almost semi-circular thecae. In the specimens sectioned from the Bala rocks the outline is indistinguishable from that of *Glyptograptus*, although whether this arises from a trend from a rectangular cross-section can only be determined when specimens have been obtained from lower horizons.

In the examples secured from the *Staurocephalus* Beds of Cautley no septum is apparent until the level of th 2^1 is reached, when it appears on both sides of the rhabdosome. Of the specimens collected from the Red Vein at Corris, 10 out of 26 possessed the characters of those at Cautley, whilst only 3 out of 16 were to be found at Llangranog (Red Vein). A few of the Corris specimens showed a septum delayed on both sides of the rhabdosome until the level of the 21st thecal pair, although it is difficult to estimate their frequency owing to the scarcity of complete forms bearing more than 20 thecae on each side. It is certain, however, that in the examples from Llangranog there are a good number in which the septum does not appear even at the 21st thecal pair. In this area, too, there are many forms which do not exhibit an abbreviated rhabdosome and which often measure up to 6 and 7 cm. in length. Unfortunately the specimens obtained are all flattened and their septal characters indeterminate.

It may be suggested tentatively that evolution took place by a gradual loss of the septum on both sides and that *Orthograptus truncatus* mut. *ashgillensis* (Fig. 7) and *Orthograptus truncatus* mut. *corrisense* (Fig. 8) are stages the intermediate terms between which have yet to be found.

What significance the loss of the septum has with regard to the internal economy of the graptolites is not clear, although such a loss would theoretically be an obvious resultant of the merging of the two stipes of a *Dicellograptus*.

It should be noted that in all cases the specimens occur with *Dicellograptus anceps*.

Climacograptus aff. *scalaris* (Hisinger). (Figs. 26–31.)

In common with other *Diplograpti*, *Climacograptus scalaris* shows a decided change in form when traced upwards from the Bala to the Lower Birkhill.

---

[1] "Ontogenetische Entwicklung und Biologie von Diplograptus und Monograptus" (*Palaeontologische Zeitschrift*, Band iii, Heft 4).

[2] Geol. Mag., Vol. X, 1873, p. 500.

In the lower beds the specimens all belong to the variety *miserablis*, but only in rare cases is the septum developed at all (*C. scalaris* mut. *indivisus* nov.). In a few examples found, this structure begins near the extreme proximal end on both sides of the rhabdosome, this habit being similar to that in the great majority of forms at the base of the Birkhill.

Within the latter division the varieties *miserablis* and *normalis* are found but there is no distinction other than that of size.

The septum is complete on the obverse side, but some slight variation takes place when the reverse side is considered.

About the base of the zone of *Akidograptus acuminatus* swarms of *Climacograpti* occur which possess no septum on the reverse side until the level of the fourth thecal pair. These are exactly similar to *Climacograptus scalaris* in their mode of growth and differ mainly in the possession of a prominent proximal spine, a more tapering proximal portion, and the nature of the septum, and they have undoubtedly evolved from the earlier form given. Intermediate mutations whose septa begin at various points between the end of the rhabdosome and the fourth thecal pair are to be found in fair numbers in the beds about the upper part of the zone of *Glyptograptus persculptus*. Higher in the succession and occurring with the *Dimorphograpti* is *Climacograptus tornquisti*, the septum in which does not commence until the level of the eighth thecal pair. Here evolution has not only taken place in the position of the septum, but also in a general caudation of the proximal end which possesses relatively huge spines. It is possible, too, to find specimens in which the septum on the reverse side is still further delayed.

There is little doubt also that *Climacograptus rectangularis* evolved along a parallel line which does not show the caudation.

Glyptograptus (?) *avitus* sp. nov. (Fig. 21.)

Probably elliptical in cross-section. Rhabdosome measuring 1 to 1·5 cm. in length. Greatest width 1·5 mm. Sicula small, with conspicuous virgella and nema projected beyond distal portion. Thecae 9 or 10 to 1 cm. and of same general type as *Dimorphograptus elongatus*,[1] with sharp sigmoid curvature. Apertural margins horizontal.

Description.—This form, while probably possessing an elliptical cross-section like *Glyptograptus*, has thecae which are quite distinct in having a sharp sigmoid curvature and long free edges. It is a characteristically small form, being never more than 1½ cm. long in the specimens obtained. After widening rather abruptly in the proximal portion it maintains a gradual but almost imperceptible increase in breadth throughout. The virgula is commonly very pronounced, and is produced for some distance below the sicula.

The sicula itself is of somewhat the same type as that of *Glypto-*

---

[1] *Monograph of British Graptolites*, p. 358.

graptus persculptus but never has a length of more than 1 cm. Growth is apparently attained in a similar manner to that of the above mentioned *Glyptograptus*. *Glyptograptus avitus* itself is almost indubitably derived from the better known form.

The thecae in the proximal region are longer than those towards the distal portion, but the general characters are the same throughout.

It is probably the forerunner of *Akidograptus ascensus* to which it is very similar in the characters of the distal end. The elongation of the proximal thecae seems to be the first stage in the caudation which leads to the later *Dimorphograpti*.

Affinities.—As stated before, distal portions are indistinguishable from those of *Akidograptus ascensus*, but no confusion can arise when the whole rhabdosomes are compared.

Horizon and Locality.—L. Birkhill Shales. South Scotland, Dobb's Linn.

Genus.—Diplograptus.

Sub-genus.—Akidograptus[1] nov.

Diagnosis.—Rhabdosome asymmetrical. Elliptical in cross-section. Transient between *Diplograptus* and *Dimorphograptus*. Thecae sub-cylindrical. Ventral walls variable.

Description.—This new genus is a transient form between *Diplograptus* and *Dimorphograptus*, being superficially like the former, but with no definite uniserial portion. The rhabdosome is elliptical in cross-section, usually with a relatively small minor axis to the ellipse. The genus is extremely protracted in the proximal portion and the sicula is covered on one side only. The thecae, although rounded in cross-section, vary in shape between those of *Climacograptus* and *Orthograptus*.

Genotype.—Akidograptus ascensus sp. nov.
Species.—Akidograptus acuminatus (Nicholson).
,, *ascensus* sp. nov.

Akidograptus ascensus sp. nov. (Figs. 22–4.)

Rhabdosome usually 1 cm. in length. Proximal portion extremely caudate. Sicula long with conspicuous virgella. Thecae about 9 to 1 cm. Septum complete.

Description.—This form is not a true *Dimorphograptus* in that it does not possess a uniserial portion, but stands in the same relation to species of that genus as *Akidograptus acuminatus*, to which it is very similar in all except the thecal characters. Both are incipient *Dimorphograpti* in the nature of their caudation.

In cross-section it is seen to be elliptical, but with a minor axis relatively less than that of the *Glyptograpti*. The measurement from the base of the sicula to the aperture of th 1^1 is a mm., whilst the biserial portion never seems to exceed 1·5 mm. in breadth.

---

[1] From Akis = a sharp point, a thorn.

Its virgella arises from a pronounced projection of the apertural margin of the sicula which in itself has a length of about 1½ mm. The nema is completely free at its distal end. Th 1^1 arises from the dorsal side of the sicula and grows downward for a very short distance and then directly upward, th 1^2 apparently arising from th 1^1 about halfway up. The distal thecae are shorter and pronouncedly similar to those of *Dicellograptus elongatus* with excavations occupying nearly half the width of the rhabdosome. They overlap for about half their length, whilst the free portion of the wall is fully equal to half the length of the theca and to three or four times that of the excavation. The thecal aperture is slightly concave.

Affinities.—*Akidograptus ascensus* is similar in its distal portion to *Dimorphograptus elongatus* and *Glyptograptus avitus*, but is easily distinguishable from these forms in the nature of its proximal end.

Horizon and Localities.—L. Birkhill. Zone of *Akidograptus acuminatus*, South Scotland, Dobb's Linn.

Akidograptus acuminatus mut. *praematurus* nov. (Fig. 25.)

Rhabdosome about 1 cm. long. Greatest width 1·5 mm., tapering. Sicula prominent with one side free. Thecae of general *Orthograptus* type about 10 to 1 cm.

Description.—This is an early form of *Akidograptus acuminatus*, being similar in nearly all its constituent characters to that species. It is, however, somewhat shorter and not drawn out to such an extent at the proximal end. It is possible, too, that in cross-section it is somewhat stouter.

The thecae are relatively long and narrow and overlap to two-thirds of their length, whilst the aperture is often denticulate.

Associates.—This form occurs with the somewhat later mutations of *Glyptograptus persculptus*.

Occurrence.—Zone of *Glyptograptus persculptus*, Lower Birkhill. Lake District, 300 yards west of Torver Beck, Coniston.

The Growth of and Variation in Glyptograptus aff. *persculptus* Salter.[1]
(Figs. 11–20.)

Salter's original specimens of *Glyptograptus persculptus*, which were undescribed by him, although afterwards mentioned by Carruthers,[2] were obtained from the Gold Mines at Pumpsaint in Carmarthenshire. A shatter belt in this area has affected more particularly the beds in the vicinity of the Silurian-Ordovician boundary, and just above the junction they contain excellent graptolites, in common with this horizon throughout Wales. The exact characteristics of Salter's type, however, are doubtful, owing to the fact that there is some variation within the specimens found at this horizon, and it is by no means certain where Salter's holotypes are.

---

[1] *Monograph of British Graptolites*, p. 257.

[2] Carruthers, Geol. Mag., Vol. V, 1868, p. 130.

Growth of Glyptograptus aff. *persculptus*. (Fig. 11*a*.)—Owing to the fact that these specimens are beautifully preserved in pyrite it has been possible to section them and so determine the mode of growth. Whilst the fine structures as may be seen in chitinous specimens are lost, nevertheless the graptolite suffers much less from distention and no difficulty is obtained in making out the component parts if the pyrite is fresh.

Sectioning is attained by rubbing down on a fine corundum stone, and measurements made with a rule graduated to 100ths of an inch. Special care has to be taken in the initial process of grinding the proximal end as here changes take place rapidly in the structures disclosed.

The bud arises in the case of *Glyptograptus persculptus*, as with other *Diplograpti*, from the side of the sicula wall. Some distance below the apex of the latter structure an infold appears somewhat nearer the obverse than the reverse side. This gradually gives place to a growth downward which is the beginning of th 1^1. The latter continues in this direction until a point is reached somewhat below the aperture of the thecae when it turns directly upward and slightly outward. No bud is apparent to give rise to th 1^2 which grows directly from th 1^1 by crossing behind the sicula. Th 1^2, in turn, grows across, giving rise to th 2^1. Alternation of growth then ceases and the thecae arise from those directly below.

It will be seen that *Glyptograptus persculptus* is noticeably different in its mode of growth from that of *G. tamariscus*.[1]

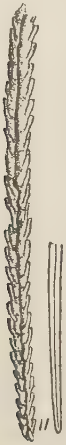
Variation in Glyptograptus aff. *persculptus*. (Figs. 11–20.)—The horizon of Salter's type specimens can be determined to within very narrow limits. In the immediate vicinity of the galleries which have been made to secure the gold, the deposits are mainly Bala together with very low horizons within the Lower Silurian. In other parts of Central Wales, as is the case here, the graptolites are confined to one or two bands within some 8 feet of the base, and as a rule it is one band only which contains specimens in abundance. Whilst, however, it is certain that the horizontal range is a very restricted one, no assertion can be made as to the precise nature of Salter's holotypes. Topotypes show a fairly wide variation, and I have compared them with specimens obtained from Nant-y-Caws (Ystradffin), Carmarthenshire, together with others from the Upper Irfon.

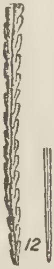
Although I have obtained a similar series elsewhere, I propose to deal with the mutations obtained from Ystradffin. Here I obtained *Glyptograptus persculptus* from seven different horizons.

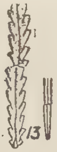
---

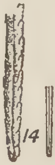
[1] W. F. Whittard, *An. Mag. Nat. Hist.*, vol. xix, 1927, pp. 469 et seqq.

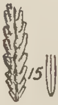
The junction of the Ordovician and Silurian in this area—that is, the lithological boundary which is so typical of other areas in Wales—is seen at the top of a disused slate quarry. This latter, together with a stream which flows through it, make a complete section through

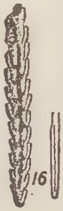


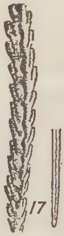


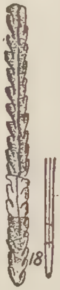


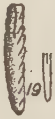












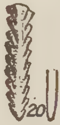


FIG. 11.—*Glyptograptus persculptus* mut. Obverse view. × 2¼ (and natural size). Zone of *G. persculptus*. Nant Rhestr, Abergwesyn, Breconshire.

FIG. 12.—*Glyptograptus persculptus* mut. Obverse view. × 2¼ (and natural size). Zone of *Akidograptus acuminatus*. Dobb's Linn, Moffat.

FIG. 13.—*Glyptograptus persculptus* mut. Obverse view. × 2¼ (and natural size). Zone of *G. persculptus*. Nant y Caws, Ystradffin, Carmarthenshire.

FIG. 14.—*Glyptograptus persculptus* mut. Obverse view. Small specimen. × 2¼ (and natural size). Base of Birkhill. 300 yards west of Torver Beck, Coniston.

FIG. 15.—*Glyptograptus persculptus* mut. omega nov. Obverse view. × 4½ (and natural size). Zone of *Akidograptus acuminatus*. R. Irfon, Abergwesyn, Breconshire.

FIG. 16.—*Glyptograptus persculptus* mut. Reverse view. × 2¼ (and natural size). Zone of *G. persculptus*. Nant y Caws, Ystradffin, Carmarthenshire.

FIG. 17.—*Glyptograptus persculptus* mut. Reverse view. × 2¼ (and natural size). Zone of *G. persculptus*. Nant Rhestr, Abergwesyn, Breconshire.

FIG. 18.—*Glyptograptus* mut. Reverse view. × 2¼ (and natural size). Zone of *G. persculptus*. Nant y Caws, Ystradffin, Carmarthenshire.

FIG. 19.—*Glyptograptus persculptus* mut. Reverse view. × 2¼ (and natural size). Base of Birkhill. 300 yards west of Torver Beck, Coniston.

FIG. 20.—*Glyptograptus persculptus* mut. omega. Holotype. Reverse view. × 2¼ (and natural size). Zone of *Akidograptus acuminatus*. R. Irfon, Abergwesyn, Breconshire.

the greater part of the Lower Birkhill. At the top of the quarry the doubly cleaved shales of the Bala give place to the dark blue finely cleaved shales of the Silurian, and some 3 feet above the junction they yield *Glyptograptus persculptus*. The specimens are usually small and are rarely composed of more than a half a dozen thecae on both sides of the rhabdosome. In constituent features, however, they are exactly like those obtained from Pumpsaint and show a similar variety in the nature of the septum on the reverse side. In most cases this begins about the top of th 1^1, but in a few cases it is delayed until the incoming of th 3^1.

The shales are then succeeded by pale grey mottled mudstones, which dip into the well of the quarry. Some 7 feet above the blue shales the mudstones contain a thin band of a darker rock which is literally packed with well preserved specimens of *Glyptograptus persculptus*. These are, on the whole, more robust than the specimens found in the lower band and usually possess a larger nunber of thecae. Their individual characters are, however, very similar and the same variation takes place within the septum. The specimens whose septa begin at any early stage greatly outnumber those where these structures begin later, although, until a collection be made of many specimens from the basal band, it will not be possible to make an exact comparison with that horizon.

At the bottom of the quarry the mottled grey mudstones give way to rusty weathering blue shales which near the base yield further specimens. Here, however, I was only able to secure some 4 or 5 complete graptolites, and an examination showed that the septum began very little later than was the case in the examples from lower bands.

A little farther on towards the mouth of the quarry and some 40 feet from the base of the Birkhill, however, the shales yielded specimens, the majority of which the septa on the obverse side began at the top of th 4^1. This feature is characteristic of examples secured from slightly higher beds.

The beds which lie in the stream bed just beyond the shale heap from the quarry, are over a hundred feet above the base. Here thin grit bands are intercalated amongst the shales, and fossils are few and far between. Some twenty or thirty yards downhill from the base of the shale heap I have obtained specimens of *Glyptograptus persculptus* from the thin grit bands. These are very imperfectly preserved in chitin but sufficiently to show that in many cases the septum was still further delayed until the sixth or seventh thecal pair.

At the top of the zone of *Akidograptus acuminatus*, about 500 ft. above the base of the Silurian, the beds yield specimens all of which possess no septa on the reverse side.

In comparing these bands with other areas in Central Wales these peculiarities are substantiated, although synchronous bands are not easily traceable. At Pumpsaint and along the Upper Irfon in Breconshire the bands near the base contain examples with an almost complete septum, but this feature gradually changes as one ascends in the succession. I have obtained also one or two of these graptolites from a band 8 feet from the base in Breconshire, which possess abnormally long rhabdosomes and in which some short distance from the distal end, on the reverse side, the septum is again absent.

In the intermediate beds, i.e. about the base of the zone of *Akidograptus acuminatus*, a graptolite occurs which is very like *Glyptograptus persculptus* in the character of its thecae but is elongated in the manner of the *Akidograptus*. This is particularly illustrative of the parallel development which takes place within the several evolutional lines at these horizons.

In the Moffat area *Glyptograptus persculptus* is by no means so prolific and on the whole the specimens are smaller than those in Wales. Here, however, owing to the crushing induced by the cleavage, specimens in full relief are rare. From the base of the black shales with *Climacograptus scalaris* var. *normalis* I have obtained a few good examples and these seem to be of the earlier types.

The Lake District on the other hand yields a fairly wide variation in this form. About 200 yards to the east of Torver Beck the band at the base of the Silurian yields *Glyptograptus persculptus*, in which the septum begins at the base of th 8^1. In the many dozen examples I collected, little or no deviation from this was noticeable. At Appletreeworth the base yields specimens showing a complete loss of a septum on the reverse side whilst to the east, early forms with that structure more complete, are found. In point of size the Lake District mutations seem to be intermediate between those of Wales and the Moffat area.

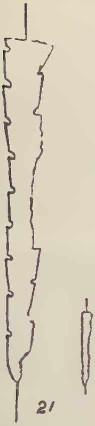
It is interesting to note that the mutations at higher horizons are much more uniform in nature and the variation between specimens from the same bands typical of the lower horizons is not seen. The twist in the thecae, too, seems to be less marked in the higher beds.

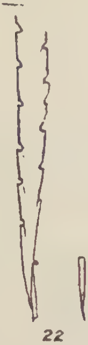
With regard to the crushing of the specimens it should be noted carefully that *Glyptograptus persculptus* may assume a variety of outlines in this manner. Special care is necessary in distinguishing it from *Mesograptus modestus*, and I have no doubt but that many of the examples called by the latter name should be attributed to the former.

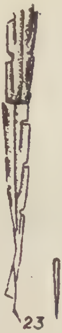
It is possible that the mutation *Glyptograptus persculptus* mut. *omega* may be found to be synonymous with *Mesograptus modestus*, but, as yet, no specimens of the latter in full relief have been obtained from the type area (Moffat).

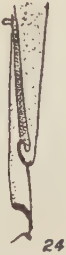
I have secured forms in relief which, being partially crushed, exhibit a concavo-convex section and it was only upon further examination of other examples and by sectioning the proximal end that definition was possible. Somewhat different outline is obtained, too, by the crushing of chitinous specimens and those preserved in pyrite.

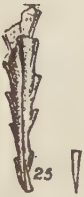
Author's Note.—All the specimens figured and described above have been placed in the collection of the Sedgwick Museum.

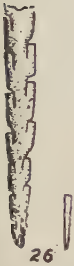


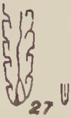


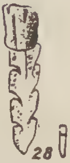


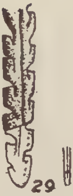


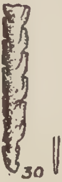












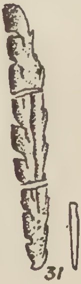


FIG. 21.—*Glyptograptus* (?) *avitus* sp. nov. Holotype. Reverse view. × 4½ (and natural size). Zone of *Akidograptus acuminatus.* Dobb's Linn, Moffat.

FIG. 22.—*Akidograptus ascensus* sp. nov. Obverse view. Paratype. × 4½ (and natural size). Zone of *Akidograptus acuminatus.* Dobb's Linn, Moffat.

FIG. 23.—*Akidograptus ascensus* sp. nov. Holotype. × 4½ (and natural size). Reverse view. Zone of *Akidograptus acuminatus.* Dobb's Linn, Moffat.

FIG. 24.—Sicula of *Akidograptus ascensus.* × 20.

FIG. 25.—*Akidograptus acuminatus* var. *praematurus* nov. Holotype. Obverse view. × 4½ (and natural size). Base of Birkhill, 300 yards west of Torver Beck, Coniston.

FIG. 26.—*Climacograptus scalaris* mut. *indivisus* nov. Holotype. Obverse view. × 4½. Red Vein, Penbryn Sands, Cardiganshire.

FIG. 27.—Typical *Climacograptus scalaris* var. *miserablis* E. & W. Obverse view. × 4½ (and natural size). Zone of *Glyptograptus persculptus.* Abergwesyn, Breconshire.

FIG. 28.—*Climacograptus scalaris—C. medius* transient. Obverse view. × 4½ (and natural size). Zone of *Akidograptus acuminatus.* Dobb's Linn, Moffat.

FIG. 29.—Typical *Climacograptus scalaris* var. *normalis* Lapw. Showing obverse and reverse portions. × 4½ (and natural size). Dobb's Linn, Moffat.

FIG. 30.—*Climacograptus scalaris* mut. *indivisus* nov. Reverse view. × 4½ (and natural size). Red Vein, Corris, N. Wales.

FIG. 31.—*Climacograptus scalaris—C. medius* transient. Reverse view. × 4½ (and natural size). Zone of *Akidograptus acuminatus.* Dobb's Linn, Moffat.

II. STRATIGRAPHICAL NOTES.

UPPER BALA.

The term Ashgillian now more generally in use for the upper portion of the Bala was defined by Professor Marr in 1905,[1] in terms of the succession at Ashgill on the western side of Lake Coniston. Unfortunately no graptolites have been recorded from these beds and subsequent correlations with the graptolite facies have had little or no foundation.

In the Monograph of British Graptolites the Ashgillian was defined as the zones of *Dicellograptus complanatus* and *D. anceps*[2] and has since been accepted as such, though in 1913 Professor Marr found *Dicellograptus anceps* at the base of the Ashgillian at Cautley,[3] in which area graptolites occur in conjunction with a shelly fauna.

I now propose to deal with the faunas of the Upper Ordovician in the several areas in turn, commencing with the classic South Scottish country where the foundation of graptolitic zoning was laid.

Moffat.[4]—The restricted number of species hitherto recorded in this region in the Upper Bala (Upper Hartfell) forms only part of the fauna, for many forms occur which range from lower horizons or are modifications of earlier types.

At the top of the zone of *Pleurograptus linearis* I have collected fossils in the following order:—

Horizon 3 *Mesograptus foliaceus* (Murch.), *Mesograptus* spp.
,, 2 *Climacograptus styloideus* Lapw. (common), *Dicellograptus forchammeri* (Gein.) (rare).
,, 1 *Pleurograptus linearis* (Carr.), *Orthograptus truncatus* (Lapw.), *O. truncatus* var. *pauperatus* E. & W., *O. truncatus* var. *socialis* E. & W. (common).

Dr. Elles informs me that at other localities not visited by me in the Moffat area, *Climacograptus styloideus* occurs in a band at the top of the *Pleurograptus linearis* zone. Some of the *Mesograpti* in the top band are very like the specimens of Hisinger's types of *Diplograptus pristis*, others show affinities with *Mesograptus foliaceus*, but are without the typical loose habit of the latter species. On the whole they are so poorly preserved that I refrain from definite identifications until many more examples have been secured (Fig. 1).

The black shales with the fossils mentioned above are followed immediately by a series of grey and green mudstones which at Dobb's Linn are about 30 ft. thick, and contain no graptolites except in a two inch black shale band about a third of the way up. This shale, especially in the Corrie section, where it is well exposed, has yielded excellent specimens of *Dicellograptus complanatus* Lapw.,

---

[1] Presidential Address, *Q.J.G.S.*, vol. lxi, 1905, pp. lxxxi, etc.
[2] *Monograph of British Graptolites*, p. 526.
[3] *Q.J.G.S.*, vol. lxxi, 1915, pp. 189 et seqq.
[4] Ibid., vol. xxxiv, 1878, pp. 240–346.

Silurian.	Zone of *Orthograptus vesiculosus*.	Zone of *Monograptus atavus*.
L. Birkhill (part of)	Zone of *Diplograptus* (= *Akidograptus*) *acuminatus*.	Zone of *Cephalograptus* (?) (= *Akidograptus*) *acuminatus*. Zone of *Glyptograptus persculptus*.

	Moffat.	Girvan.	Cautley.	Lake District.		Berwyns.	Corris.		Conway.	Haverfordwest.	
Ordovician. U. Hartfell.	Zone of *Dicellograptus anceps*.	Drummuck Group.	Ashgill Shales.	Ashgill Shales.	Ashgillian.	*Trinucleus* Mudstone.	Garnedd Wen Mudstones. Narrow Vein.	Bala (W. J. Pugh and A. H. Cox).	*Phacops* Mudstone.	Slade and Redhill Beds.	Bala (Geol. Survey, 1909).
			Staurocephalus Beds.	*Phacops mucronatus* Beds. Ash. Limestone.						Sholeshook Limestone	
			Phacops robertsi Beds.	*Phillipsinella* Beds.		*Phillipsinella* Beds.	Red Vein.		*Trinucleus* Mudstone.		
L. Hartfell.	Zone of *Dicellograptus complanatus*.	Barren Flagstones.	*Calymene* Beds.	*Calymene* Beds.	Caradocian.		Abercwmeiddaw Beds.			Robeston Wathen Limestone.	
	Zone of *Pleurograptus linearis*.	Whitehouse Group (*Dionide* Beds).				Pen-y-Garnedd Shales.	(*Cyclopyge* fauna) Nod Glas		*Dicranograptus* Shales.	Mydrim Shales.	
	Zone of *Dicranograptus clingani*. Zone of *Climacograptus wilsoni*.						Ceiswyn Beds.				
							Volcanics.			Mydrim Limestone.	

which lie in full relief on the plane between the black shales and the grey mudstone. Other forms recorded from the shales are *Orthograptus truncatus* var. *socialis* E. and W., *Climacograptus supernus* E. and W., *Cl. scalaris* var. *normalis* Lapw., and *Mesograptus* spp. With the exception of the *Mesograpti* which are rare, the assemblage seems to consist of stunted forms. Indeed, *Dicellograptus complanatus* itself could easily be mistaken for a small *Dicellograptus forchammeri* but for the fact that the thecae are much more definitely introverted in the latter species.

With the incoming of soft black shales at the top of the Barren Mudstones fossils appear once more. This succeeding group, which consists of alternating greenish unfossiliferous shales and dark soft fossiliferous mudstone and shale, has been called by Professor Lapworth the zone of *Dicellograptus anceps*. An examination of these deposits has shown them to contain a large variety of fossils although little or no change in the assemblages at various horizons is shown throughout. The following are the forms recorded :—

Dicellograptus anceps (Nich.) (common), *D. complanatus* var. *ornatus* E. and W. (rare).

D. complanatus var. *complexus* nov. (rare), *Orthograptus truncatus* var. *abbreviatus* E. and W. (common), *Orthograptus fastigatus* sp. nov. (common).

Climacograptus supernus E. and W., *Cl. scalaris* var. *miserablis* E. and W., *C. tuberculatus* Nich. (rare).

The specimens of *Orthograptus truncatus* occur more especially in a band at the base, but are fairly plentiful higher in the zone. The varieties of *Dicellograptus complanatus*, which also occur low down, are interesting in being twined (Fig. 3) and in possessing large proximal spines. It should be noted also that the specimens are no more robust than those of *Dicellograptus complanatus* times, when it has been suggested they lived under unfavourable conditions.[1]

The *Mesograpti* are transients between the earlier types and *Mesograptus modestus* of the Lower Silurian whilst many of the specimens which have been referred to *Climacograptus supernus* are of the true *bicornis* type, since they possess in addition to spines up to 1 cm. in length, the more robust rhabdosome of the latter. The spines, too, involve the whole of the basal thecae in their growth in contrast to the more restricted growth in the *C. supernus*.

The Lake District and Yorkshire.—Although Professor Marr and other investigators have worked for many years upon the series of rocks on the western side of Lake Coniston, and from which the term Ashgillian has sprung, no graptolites have yet been recorded from this area. I, myself, have spent some fruitless weeks searching the very narrow strip which constitutes the Ashgillian Series.

In 1916 Professor Marr [2] made a very close correlation between the shelly faunas of the Coniston and Cautley[1] areas, and as the latter contains graptolites in addition, a means of comparison between the respective faunas was possible. Here *Dicellograptus anceps* is first found just above the base of the Ashgillian, i.e. the *Phacops robertsi* Beds. I have found *Dicellograptus anceps* well down in the *Phacops robertsi* Beds of the Rawthey Stream, and also in the *Staurocephalus* Beds above. Professor Marr also records it from the *Phacops robertsi* Beds in Taythes Gill. It occurs in conjunction with *Orthograptus truncatus* var. *abbreviatus* E. and W., and it is interesting to note that the specimens are excellently preserved in pyrites even to the conspicuous spines on the earlier thecae. Thus it would seem that the term Ashgillian implies only the zone of *Dicellograptus anceps*, and that very little, if any, of the zone of *Dicellograptus complanatus* is present. Whether the latter represents the upper portion of the *Calymene* Beds below or whether a hitherto unnoticed break occurs remains to be proved. In any case it seems necessary to use a dual system of nomenclature, one for the shelly and one for the graptolites facies.

---

[1] G. L. Elles, Geol. Mag., Vol. LXII, 1925, p. 343.
[2] *Q.J.G.S.*, vol. lxxi, 1915, p. 189 et seqq.

In the *Staurocephalus* Beds *Dicellograptus anceps*, *Orthograptus truncatus*, and *Climacograptus scalaris* var. *miserablis* occur both in the beds above and below the volcanics. The specimens are in a poor state of preservation, being mere films showing signs of intense cleavage. I have recorded a rather doubtful specimen of *Climacograptus scalaris* var. *miserablis* from the Astgill Shales of Backside Beck, but here as in the Coniston area these beds seem to contain only shelly fossils.

Wales.—It is extremely unfortunate that in this area where the Bala rocks are represented by huge thicknesses of sediments graptolites are rare except towards the base of the series. Well down in the Bala Series throughout Wales occurs a band of black shales whose fauna can be closely compared even in such divergent areas as Conway[2] and Haverfordwest.[3] The assemblage on the whole suggests the zone of *Dicranograptus clingani* although there are many local variations. Towards the top of this band, in most areas, an abundance of *Orthograptus truncatus* occurs forming a link between *Orthograptus truncatus* (s.s.) and var. *abbreviatus* of the higher beds. The *Pleurograptus linearis* zone as defined in Moffat by *Pleurograptus* and *Leptograptus* has no definite equivalent in Wales.

The enormous multiplication of the contemporaneous deposits in Wales, where they are some 7,000 ft. thick (near Llanwrtyd) as compared with 78 ft. at Moffat, together with the lack of fossils in the former area, make comparison doubly difficult.

An interesting comparison with regard to the black shale band can be made between the Conway and Haverfordwest areas where the graptolites horizons have been carefully worked out by the respective workers. The *Orthograptus truncatus* Shales which lie at the top of the black shales in the latter area can be closely compared with the uppermost bands in the former, with the exception that specimens of *Dicranograptus* are found at Conway. *Orthograptus truncatus* and its varieties occur in Moffat with *Dicranograptus nicholsoni* and *D. ramosus* in the zone of *Dicranograptus clingani*. In the Corris[1] and Llanwrtyd areas the *Dicellograpti* occur in abundance in the black band, together with *Diplograpti*, which indicate the zone of *Dicranograptus clingani*. The shales of Pen-y-Garnedd[2] seem to be of a somewhat higher horizon, whilst yet not suggesting a close comparison with the zone of *Dicellograptus complanatus*. In this area the difficulty seems to be in the placing of an equivalent of this horizon after the *Phillipsinella* Beds have been placed in the zone of *Dicellograptus anceps*, which in comparison with Yorkshire is their graptolitic equivalent.

---

[1] Ibid., vol. lxix, pp. 1 et seqq.

[2] G. L. Elles, *Q.J.G.S.*, vol. lxv, 1909, p. 169 et seqq.

[3] *Memoir of Geol. Survey*, 1914, p. 37 (Haverfordwest).

It has been suggested by Dr. Elles[3] that the general stunting of the forms found at Moffat within the band with *Dicellograptus complanatus* is possibly due to the fact that it is a pathological horizon and that elsewhere it is a part of the *Dicellograptus anceps* or *Pleurograptus linearis* zone. This localized occurrence would therefore overcome the difficulty of correlation elsewhere. It would seem necessary, however, on this plan, to place the thin black band of Moffat within the zone of *Pleurograptus linearis*, in which case *Dicellograptus complanatus* would represent a stunted form of *Dicellograptus forchammeri*. As, however, has been pointed out before, the cell form in the supposedly similar species is undoubtedly different, although it may have acquired this difference within the upper part of the zone of *Pleurograptus linearis*. It must be noted, too, that the " Barren Mudstone " type of sediment is also present in Wales, although shelly bands are intercalated.

In Wales, as in Northern Britain, transient forms occur, connecting the faunas of the Ordovician and Silurian. *Climacograptus scalaris* ranges up from the *Dicellograptus anceps* zone, and even lower (Pen-y-Garnedd) in the variety *miserablis*. *Mesograptus modestus* has its equivalents in the *M. modestus* var. *diminutus*, which I have found in fair numbers in shales from the Gwern-y-Brain Beds of Welshpool.[4] Some Glyptograptid specimens are also to be found in the Pen-y-Garnedd shales, but they are few and too poorly preserved to be determined specifically.

SILURIAN.

In his work on the Moffat area Professor Lapworth drew the base of his Silurian at the base of a series of coal black shales which contained *Climacograptus scalaris*. These succeeded some 7 ft. of unfossiliferous mudstones at the top of the *Dicellograptus anceps* Beds. In reply to a question Professor Lapworth[1] stated that this boundary formed the chief palaeontological break, although no physical discontinuity was noticeable in the Scottish area.

---

[1] *Q.J.G.S.*, vol. lxxviii, 1923, pp. 512–13.

[2] Ibid., vol. lxxviii, 1923, pp. 487–507.

[3] GEOL. MAG., Vol. LXIII, 1925, p. 343.

[4] A. Wade, *Q.J.G.S.*, vol. lxvii, 1911, p. 419.

With increasing knowledge of the faunas of the Upper Ordovician and Silurian doubt has been cast upon the suitability of this horizon as the division between the two systems.

On purely faunistic grounds Dr. Elles[2] demarcates the base with the incoming of the *Monograpti*. Professor Jones, on the other hand, retains the old division of Professor Lapworth upon the grounds of striking lithological changes in most areas at this horizon, which make it an admirable line for mapping.

A review of the faunas and lithology in the several areas will enable us to view more clearly the several aspects of the question.

Moffat.—In Dobb's Linn the incoming of the Birkhill of Lapworth is marked by a very obvious lithological change, from the tough greenish mudstones of the Ordovician to black shales crowded with fossils (although at Belcraig, on the other hand, the former type of lithology persists as bands between the shales up to the zone of *Orthograptus vesiculosus*). Professor Lapworth called the basal 11 ft. (Dobb's Linn) the zone of *Diplograptus*[3] *acuminatus* although he did not record the zonal fossil from the 1 ft. band at the base. Elsewhere the incoming of these fossiliferous bands is marked by the presence of *Glyptograptus persculptus* and these have been separated off as a lower zone.[4]

Work on *Glyptograptus persculptus* and its varieties has served to prove the presence of this form in the Lower Valentian of both the Lake District and the South of Scotland.

In Central Wales, where the zone of *Akidograptus*[5] *acuminatus* is represented by some 700 ft. of deposits (Llanwrtyd), *Glyptograptus persculptus* shows an evolution from earlier forms with more or less complete septum on the reverse side to mutations exhibiting a complete loss of this feature. This has made a closer comparison of the horizons in other areas possible.

In the Dobb's Linn Section, unfortunately, most of the specimens are in a crushed condition, which makes detailed comparison impossible, but nevertheless I have obtained quite a number of specimens of *Glyptograptus persculptus* in full relief which have a considerable range of mutations. Excellent specimens may be obtained at the junction with the unfossiliferous beds below, and they occur in fair numbers with the crowds of *Climacograpti* in full and half relief.

With regard to the *Climacograpti* themselves they show a similar trend in the evolution of their septum on the obverse side, and I have secured many transient forms between *Climacograptus scalaris* var. *normalis* with complete septum and *Cl. medius* with the septum beginning at the level of the fourth or fifth thecal pair.[1] Forms where the beginning of the septum is still further delayed are to be found at higher horizons. Together with the loss of the earlier portions of the septum goes a caudation of the proximal portion which becomes extreme in *Climacograptus tornquisti*. Other specimens of general *Climacograptus scalaris* type have been found bearing spines (cf. *Climacograptus innotatus*), although the true *Climacograptus innotatus* Nich. seems to occur at a somewhat higher level.

---

[1] G. Lapworth, *Q.J.G.S.*, vol. xxxiv, 1878, p. 346.

[2] G. L. Elles, *Proc. Geol. Assoc.*, vol. xxxiii, 1922, p. 15.

[3] *Vide supra*, Palaeontological Notes.

[4] O. T. Jones, *Q.J.G.S.*, vol. lxv, 1909, p. 468.

[5] = *Cephalograptus* (?). *Vide* Palaeontological Notes.

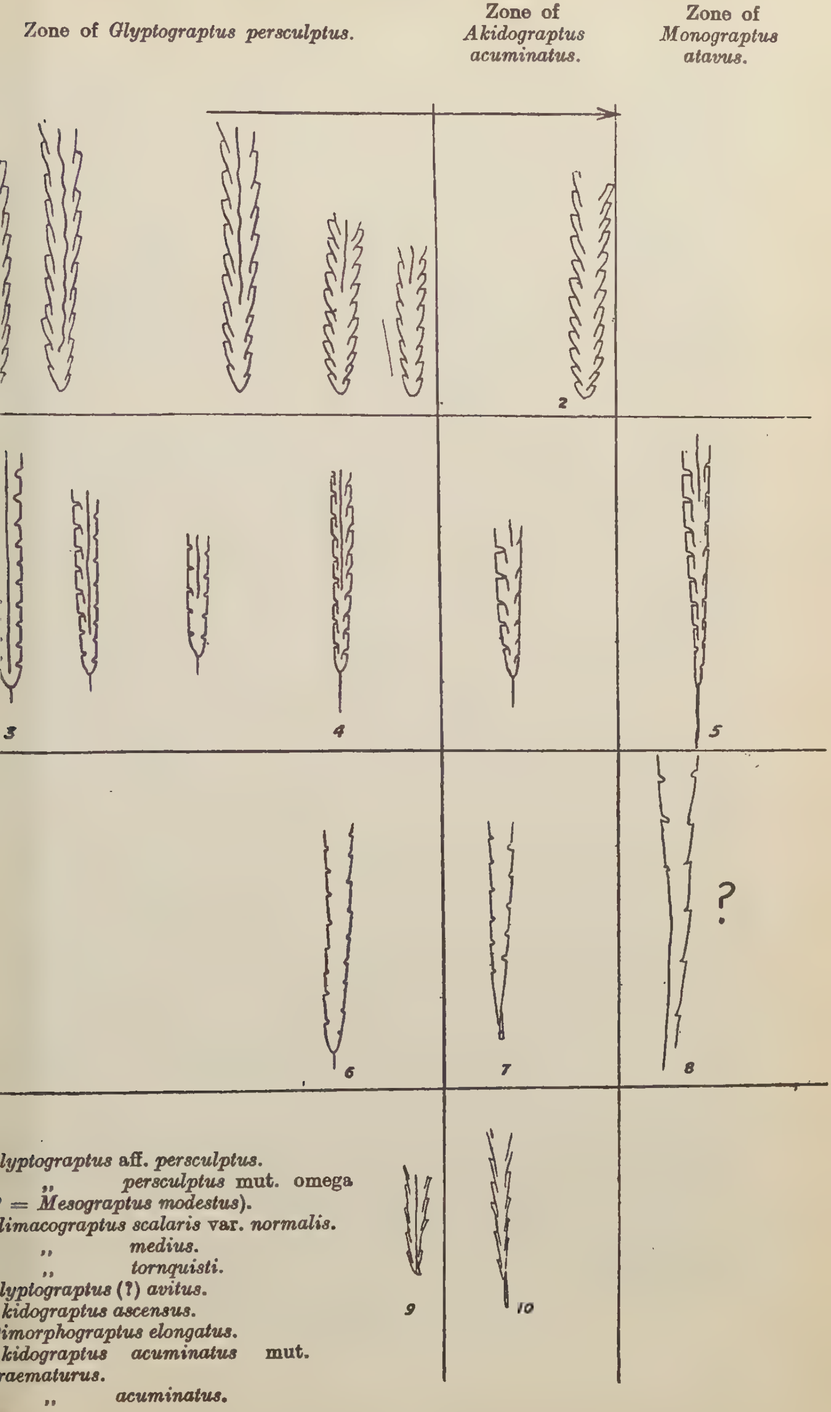
The table below indicates the position of the various species in the 11 feet or so of shales at the base of the Silurian :—

Horizon 11	*Orthograptus vesiculosus* (Nich.), *Dimorphograptus elongatus* Lapw. *Dimorphograptus* spp., *Monograptus atavus* Jones. *Climacograptus medius* Tornq. *Climacograptus scalaris* var. *miserablis* E. & W. *Climacograptus tornquisti* E. & W.
Horizon 10	*Dimorphograptus elongatus* Lapw., *Mesograptus modestus* (Lapw.). *Glyptograptus persculptus* (Salt.). *Akidograptus acuminatus* (Nich.), *Orthograptus vesiculosus* (Nich.). *Climacograptus medius* Tornq., *Cl. scalaris* var. *normalis* Lapw.
Horizon 9	*Akidograptus acuminatus* (Nich.), *Cl. scalaris* var. *normalis* Lapw. *Orthograptus vesiculosus* (Nich.).
Horizon 8	*Orthograptus vesiculosus* (Nich.), *Akidograptus acuminatus* (Nich.). *Climacograptus scalaris* var. *normalis* Lapw. *Mesograptus modestus* (Lapw.).
Horizon 7	*Mesograptus modestus* (Lapw.), *Climacograptus scalaris* var. *normalis* Lapw. *C. scalaris* var. *miserablis* E. & W., *Cl. medius* Tornq. *Akidograptus acuminatus* (Nich.).
Horizon 6	*Mesograptus modestus* (Lapw.) (common), *Climacograptus scalaris* var. *normalis* Lapw. *Cl. scalaris* var. *miserablis* E. & W., *Cl. medius* Tornq. *Akidograptus acuminatus* (Nich.).
Horizon 5	*Climacograptus scalaris* var. *normalis* Lapw. *Cl. scalaris* var. *miserablis*, *Cl. medius* Tornq. *Mesograptus modestus* (Lapw.) (very common). *Orthograptus vesiculosus* (Nich.), *Akidograptus acuminatus* (Nich.). *A. ascensus* sp. nov., *Climacograptus innotatus* Nich.
Horizon 4	*Cl. scalaris* var. *normalis* Lapw., *Cl. scalaris* var. *miserablis* E. & W. *Cl. medius* Tornq., *C. scalaris-medius* transients. *Akidograptus acuminatus* (Nich.).
Horizon 3	*Climacograptus scalaris* var. *normalis* Lapw. *Cl. scalaris* var. *miserablis* E. & W. *Glyptograptus persculptus* (Salt.), *G. avitus* sp. nov.
Horizon 2	*Climacograptus scalaris* var. *normalis* Lapw. *Cl. scalaris* var. *miserablis* E. & W. (very common). *Glyptograptus persculptus* (Salt.).
Horizon 1	*Climacograptus scalaris* var. *normalis* Lapw. *Cl. scalaris* var. *miserablis* E. & W. (very common). *Glyptograptus persculptus* (Salt.).

---

[1] *Monograph of British Graptolites*, p. 189.

Fig. 32.—Diagram illustrating the evolution in certain L. Birkhill graptolites.


Zone of *Glyptograptus persculptus.*
Zone of *Akidograptus acuminatus.*
Zone of *Monograptus atavus.*
2
3
4
5
6
7
8
?
9
10

lyptograptus aff. *persculptus.*
,, *persculptus* mut. omega
= *Mesograptus modestus*).
limacograptus scalaris var. *normalis.*
,, *medius.*
,, *tornquisti.*
lyptograptus (?) *avitus.*
kidograptus ascensus.
imorphograptus elongatus.
kidograptus acuminatus mut.
raematurus.
,, *acuminatus.*

Dr. Elles informs me that she has found a few specimens of *Orthograptus truncatus* var. *abbreviatus* Lapw. with *Akidograptus acuminatus*.

Early forms of the *Dimorphograpti* are common in the beds just above Band 10. Other features which enter into the evolution I have discussed in the Palaeontological Notes (q.v.).

The incoming of the *Monograpti* is accompanied by no lithological distinction, although the beds with *Orthograptus vesiculosus* are somewhat tougher and grittier than those below. *Monograptus atavus*, however, has not been recorded at the bottom of this zone.

Akidograptus ascensus is similar in all but the thecae to *Akidograptus acuminatus*, both being in the same evolutional stage.

Lake District and Yorkshire.—In the Yorkshire area at Cautley the junction between the Ordovician and Silurian may be seen just above the entrance of Spengill and Stockless Gill. The graptolites at the base, however, are in a very poor state of preservation and no definite study of them could be made. The same is true of the section in Watley Gill, so that the Cautley area generally does not admit of very detailed work at this horizon.

Along the western side of Lake Coniston, however, the lowest Silurian beds yield excellent fossils and here the fauna may be studied in detail, although I have confined myself to the beds below the *Dimorphograpti* Band. In this area some curious features are to be noticed. As in Scotland the incoming of the Silurian is denoted by a marked change in lithology, but the graptolites found at the actual junction show a rather wide variation. A couple of hundred yards to the west of Torver Beck is a narrow cutting into a small disused slate quarry. Here the marked lithological junction is excellently shown and a couple of inches above occurs a band crowded with *Glyptograptus persculptus*,[1] all of uniform type whose septa on the obverse side begin at about the eighth thecal pair. The form occurs well up in the *Akidograptus acuminatus* zone in Wales. In Appletreeworth Beck, on the other hand, what seems to be the basal band contains a higher form still where the septum has completely disappeared. This form is found in Wales about the incoming of the *Dimorphograpti*. East of Appletreeworth in a disused quarry a pronounced impure limestone band occurs at the junction, while above this low forms of *Glyptograptus persculptus* may be obtained. In the Ashgill quarry this limestone band has apparently disappeared.

Whilst it might be postulated that the lithological change comes in at different horizons in the several localities, this is probably not the case here, and the writer is of the opinion that there is good evidence of a break at the base of the Silurian in this area. The lack of fossils in the Ashgill Shales, however, makes this conclusion still uncertain.

---

[1] *Vide* Palaeontological Notes.

I have not examined the Browgill Section, but here *Akidograptus acuminatus* has been recorded, and it is not improbable that one will find specimens of *Glyptograptus persculptus*. Those occurring at the base, just above the *Atrypa flexuosa* band, should, however, be of an earlier type than those general along the western side of Lake Coniston.

Wales.—Before considering the faunas in this area it may be useful to offer an approximate comparison between the thicknesses of rock which intervene between the incoming of *Glyptograptus persculptus* and that of the *Monograpti* in the several areas.

In Central Wales (Llanwrtyd) the amount is 1,000 feet; in the Lake District (Browgill) 7 feet; and in the South of Scotland 20 feet.

In the first-named area the incoming of what has been termed the Valentian is marked by an even more striking lithological change than either in the Lake District or at Moffat. Fine-grained blue-black shales with a very characteristic double cleavage are succeeded by a pale mottled grey mudstone. Whilst in some areas (Machynlleth) this junction may be shown on a hand specimen, this is by no means true of the rocks of South Central Wales, where there is a gradual transition from one type to another, usually through a blackish shale. Just above the junction (8 feet q.p. in Breconshire) a band occurs which is crowded with early forms of *Glyptograptus persculptus*. For the whole distance from Dinas Mawddwy in the north almost to Carmarthen town in the south, from Rhayader in the east to Cardigan Bay in the west, this characteristic division and its contained fossils remain remarkably constant. It forms one of, if not the most easily mapped boundaries in the Silurian and Ordovician, and is in some ways comparable with the change in lithology in Northern Britain, indicating a somewhat drastic change in the conditions of deposition. In the rocks with shelly fossils, however, it is by no means certain that this change is indicated, as *Glyptograptus* cf. *persculptus* has been recorded from rocks which have been placed in the Bala of the Garth (Breconshire) area.[1] I have succeeded in getting a specimen of *Cl. scalaris* var. *miserablis* from the same beds, but the other fossils are of too poor a quality to make their identification anything but doubtful. The band is only a few feet below what were mapped as the basal grits of the Silurian.

The incoming of the *Monograpti* in Central Wales is again marked by no lithological change. Near Llanwrtyd (Breconshire) they appear in the upper half of some 800 feet of shale, which exhibits little or no difference in appearance throughout its whole vertical extent. In many places the cleavage is less pronounced and the rocks are more of the mudstone type whilst other variation is lent locally by the incoming of their grit bands and huge thicknesses of conglomerates. Even the incoming of *Akidograptus acuminatus* itself is by no means well defined in lithology.

---

[1] G. Andrew, *Q.J.G.S.*, vol. lxxxi, 1925, p. 391.

It will be seen that any attempt to draw the base of the Silurian with the incoming of the *Monograpti* must bear this fact in mind. Although it may be seen that now the faunal break at the top of the Ordovician as defined by most authors is not so marked as at first thought, yet it is in many ways none the less distinct, for at no other horizon are the graptolites so restricted as regards species and genera. Here occurs the diversification which leads through *Akidograptus acuminatus, Akidograptus ascensus*, and the *Dimorphograpti* proper to the *Monograpti*.

CONCLUSIONS AND REMARKS.

1. The zones of *Pleurograptus linearis, Dicellograptus complanatus*, and *D. anceps* contain a number of forms which have been hitherto undescribed.

2. The several faunas at the top of the first-named zone are distinct and warrant further attention. It is possible by a more accurate knowledge of the fossils at this horizon that we shall be able to determine the relative position of the faunas of the black shales which occur at the base of the Bala throughout Wales.

3. With regard to the zone of *Dicellograptus complanatus* as making a pathological or phasal horizon, the fauna, although in general made up of small forms, includes some exceptions.

4. Early forms of *Mesograptus modestus* begin within these zones and are contemporaneous with similar forms in *Mesograptus foliaceus* and *diplograptus* cf. *pristis*.

5. *Dicellograptus anceps* occurs almost at the base of the Ashgillian in the Cautley district, so that the term becomes difficult and of little use in its application to the graptolitic facies.

6. It is impossible at the present state of our knowledge to accurately correlate the graptolitic and shelly facies of the uppermost Ordovician and further difficulty may be added by gaps in the succession. Further work, especially in some of the Welsh areas where the succession is expanded, upon a detailed sub-division of the shelly fossils, is desirable. It is possible, too, that further partition of the graptolite faunas, as done in the Haverfordwest area, can be made in other districts.

7. The base of the Silurian as mapped at present forms generally the best demarcation. It is possible, too, to arrive at some degree of accuracy in its determination owing to the striking evolution of the graptolites near the base.

8. The mutations of *Glyptograptus persculptus* found near the base of the Silurian along the western side of Lake Coniston suggest a break in this area at this horizon.

9. *Glyptograptus persculptus* and *Climacograptus scalaris* var. *normalis* show a gradual loss of septum as newer beds are reached.

It is possible, too, that such forms as *Orthograptus truncatus* follow a similar trend.

10. It should be noted that evolution takes place in the character of the cross section so that the sub-generic designations concerning this factor are not hard and fast rules.

This may happen in the case of *Orthograptus truncatus* which in the upper Bala possesses an elliptical cross-section.

In conclusion I should like to tender my most grateful thanks to Dr. T. N. George and Mr. A. G. Brighton for suggestions with regard to the revision of the original typescript.

The Glacial and Recent Drainage of the Lintrathen Area.

By Douglas A. Allan, Ph.D., D.Sc., F.R.S.E.

(PLATES I–III.)

OUR knowledge of the geology of the district fringing the Grampians in Perthshire and Angus has been limited in the main to the published 1 inch maps of H.M. Geological Survey of Scotland (Sheets 48 and 56 in particular). A few papers in the *Quarterly Journal of the Geological Society* about the middle of the last century deal with certain exposures of special interest. The writer of the present contribution has conducted recently a detailed investigation of the area between Dunkeld and Fern, and an account of the solid geology has been published.[1] The glacial geology presents no less interesting material or problems and, while the major portion of the results is being held over until further field-work is undertaken, one aspect, and over a limited area, will be considered here.

As an aid to the understanding of the surface features, a brief survey of the solid geology is given. To the north and west of the district rise the Grampian Mountains, the margin of a dissected plateau which appears as a range of somewhat rounded hills with an average height of 1,500 feet. They are composed of schistose grits of the Dalradian Schist Series, which are inclined to the north-west at an angle of about seventy degrees. Intruded into them are dyke-like masses of felsite. To the south of this belt, and separated from it by a N.E.–S.W. fault, are Lower Old Red Sandstone strata, folded into a gentle syncline with a N.E.–S.W. axis. The rocks are commonly conglomerates, the comparative scarcity of joint planes in which causes them to resist denudation and to stand out as hills and ridges about 1,200 feet in height, and more easily eroded lava flows, mainly andesites and basalts but including one conspicuously acid member, the Lintrathen type dacite

---

[1] *Trans. Roy. Soc. Edin.*, vol. lvi, 1928, p. 57.

(Lintrathen porphyry of earlier writers), which is almost as topographically outstanding as the conglomerates. Still farther to the south, and immediately beyond the Highland Boundary Fault, are higher members of the Lower Old Red Sandstone Series, beginning with basaltic lava flows and passing upwards into conglomerates and finally sandstones. These beds are implicated in the steep north-west limb of the asymmetrical Strathmore syncline and dip south-eastwards at angles varying from 70° to 40° the farther away they are from this important line of dislocation. Immediately south of Lintrathen there is a complementary anticline between the Highland Boundary Fault and the Strathmore syncline. Within the southerly belt, the ground slopes from 800 feet to around 150 feet along the central axis of Strathmore. The stratigraphically lower conglomerates along the north-west margin of the strath form ranges of rounded hills with a general N.E.–S.W. orientation. Over the higher parts of the area there is a thick mantle of boulder-clay, but in Strathmore proper it is concealed largely beneath a widespread covering of fluvio-glacial sands and gravels.

The present-day drainage of the area reflects the peculiarities of rock structures and distribution just described. Within the Dalradian Schist country the streams flow in a south-easterly direction, transverse to the prevailing strike of the grits. The sides of the valleys are not conspicuously steep and the floors are almost invariably several times wider than the streams which follow zig-zag courses along them. With this peculiarity, there is a general absence of anything but rudimentary spurs. In the Lower Old Red Sandstone area the rivers display three noteworthy characteristics. Over much of their courses they flow in deep, steep-sided, rocky gorges; they attempt locally to accommodate themselves to bedding planes and joint planes; they show a marked tendency to be deflected to the east until they reach the centre of Strathmore, where a meandering course is followed among the sands and gravels.

The Isla, the principal river of modern times, displays all the features mentioned. In the earlier part of its course it occupies a transverse valley; above Milna Craig is a wide stretch of alluvial flats; below is the Reekie Linn (fall) and the long gorge of the Devil's Punchbowl and the Slug of Auchrannie (rapids) to the Den of Airlie. Below Dillavaird Bridge the Isla emerges into open country, turns south-west along Strathmore, is joined near Coupar Angus by the Ericht, and flows into the Tay at Cargill. The next transverse valley in the Dalradian Schists north-east of the Isla is occupied by the Back Water, the name of which is changed south of Dykend to the Melgam Water. As such it flows south-east in a fairly broad channel in Lower Old Red Sandstone rocks to the Loch of Lintrathen, at the south-eastern corner of which it passes out by a series of gorges and waterfalls at Bridgend of Lintrathen, Clintlaw, and Loups of Kenny, and finally turns south-west to

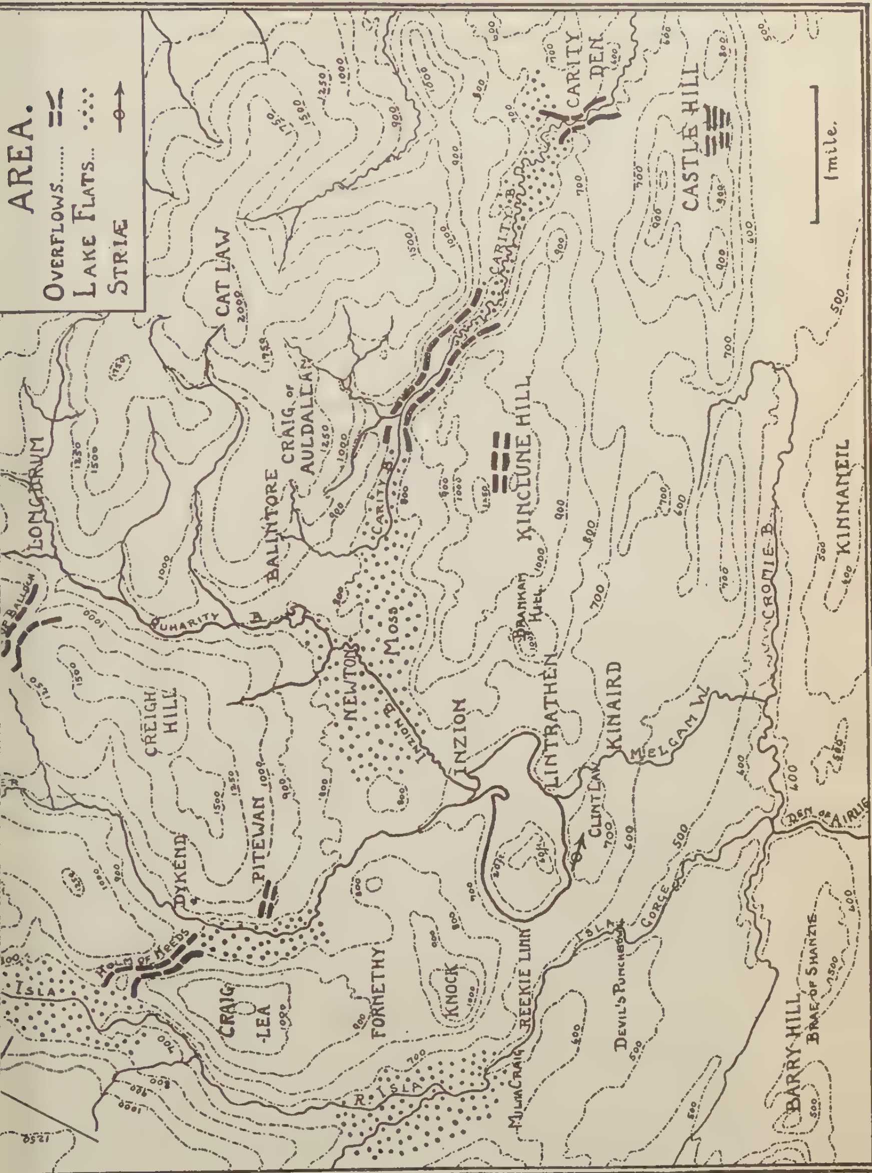


FIG. 1.—Map of the Lintrathen Area.

pon 1 in. map of H.M. Ordnance Survey, with the sanction of the Controller of H.M. Stationery Office.

join the Isla below Airlie Castle. The Cromie Burn is a small tributary on the left bank of the Melgam Water occupying a hollow along the strike of some fine-grained sandstones. The succeeding transverse valley to the north in the schists contains the Quharity Burn, the upper course of which resembles the others described. South of Balintore it enters Old Red Sandstone country, where it meanders among flats and finally follows a curiously straight course through Newton Moss, becomes the Inzion Burn, and discharges into the Loch of Lintrathen.

The drainage of the northern part of the district has a general north-easterly trend and feeds the South Esk. Both the South Esk and its most important tributary to the south-west, the Prosen, commence in transverse valleys cut through schistose grits and phyllites. In the Old Red Sandstone area the South Esk is deflected a little to the south-east, and the Prosen flows almost due east. The Carity Burn still farther to the south-west is unique in that it originates apparently as an insignificant streamlet, descending the schists to the west of Craig of Auldallan for less than a mile, flows into the eastern end of Newton Moss from the drainage of which it receives additional water, and then enters a valley conspicuous for its width, depth, and steep sides. East of Ascreavie Wood this valley opens out into alluvial flats barred to the south and east by the upstanding mass of Lintrathen type dacite, the outcrop of which is shaped like the bow of a boat, owing to the rise of the north-eastern end of the syncline. The Carity Burn meanders through the alluvial flats and passes through the dacite ridge by a deep gorge with vertical bare rock walls, finally flowing east to join the South Esk. There is a short transverse valley in the schists to the north opposite the Carity Den gorge.

From the brief description of the present-day drainage system it will be noted that, among the topographical peculiarities of the area, one of the outstanding features is the abundant remains of previous drainage phenomena. These fall into two main groups—old river valleys which are now more or less dry or carry streamlets of ridiculously diminutive size in comparison with that of their channels, and alluvial flats, often with terrace features, obviously indicative of vanished lochs. The passing of these sheets of water is to be attributed, in all probability, to diminution of the water supply, but in many cases the gorges, to which reference has been made earlier, terminate in waterfalls which represent the cutting back of the sill or ledge at the outlet of each loch. Alluvial flats of this type occur on both the derelict and the present-day river courses. Reference to this alternation of gorges with the beds of naturally drained lochs in other parts of the Southern Grampians is to be found in Sir A. Geikie's *The Scenery of Scotland* (3rd edition, 1901, p. 175).

The only loch of any considerable size between Blairgowrie and Kirriemuir is the Loch of Lintrathen, now the principal source of the water supply of Dundee. Having due regard for the number of derelict lochs throughout the district, the survival of the Loch of Lintrathen seems rather surprising. It is curious that the survivor is not only situated on a tributary stream, the Melgam Water, but is also of larger size than the naturally drained ones. While this relatively large area, 450 acres, is in part due to the work of the Dundee Water Department in erecting a dam at the south-eastern end, I am convinced, from an inspection of their 6 inch scale manuscript maps of the district, before any engineering work was undertaken (1872), when the area of the loch was 180 acres, that the present extent of the water exceeds by very little its previous maximum. The words previous maximum are used advisedly, as Sheet 56 of the 1 inch map of H.M. Geological Survey of Scotland shows that more than half of the loch had been drained by 1870, presumably by the erosion of the outlet of the Melgam Water at Bridgend of Lintrathen. More striking still is the fact shown by the same map that the *limit of natural drainage* had been reached, for the Melgam Water from Inzion to Lintrathen flowed through alluvial flats representing the old floor of the loch, and was separated from the surviving remnant, which lay in the extreme south-west of the original basin, by a stretch of 700 feet of dry land.

A geological examination of the neighbourhood of the loch shows that it rests mainly on Lower Old Red Sandstone conglomerate, a particularly resistant rock, as the adjacent Knock of Formal (1,158 feet) to the west and Brankam Hill (1,017 feet) to the east testify, and was excavated apparently against the dip of the strata. The south shore is, and seemingly throughout its history has been, composed of the tough Lintrathen type dacite, which rises up below the conglomerate and has an approximately northerly dip of about thirty degrees. Between the dacite and the overlying conglomerate are basaltic lavas and ashes. At Milna Craig, above the Reekie Linn, a loch once existed with similar structural relationships and an equally stout buttress at its lower end, but the Isla gorge has been cut and the loch drained completely. The overflow from the Loch of Lintrathen was not southward over the dacite barrier, but eastward by falls, rapids, and gorges excavated along the junction of the dacite with the more readily eroded basalts and ash beds until at Kinaird the acid lava is cut out against the Highland Boundary Fault and the Melgam Water crosses to the higher members of the Lower Old Red Sandstone sequence. As this process drained the northern and eastern parts of the loch and left the south-western part isolated, either the Melgam Water outlet is a comparatively recent development, or else the loch is peculiar in that its deepest part is well off the main direction of water-flow through it. The formation of the floor of the Loch of Lintrathen was investigated by Sir John Murray and Mr. Laurence Pullar in June, 1903, and in *A Bathymetrical Survey of the Freshwater Lochs of Scotland* (1910) there is a description in vol. ii, pt. i, p. 123, and a bathymetrical map in vol. iii, pl. 33. They refer to it as " a simple basin, the bottom sloping down, with few irregularities, to the deepest part, which is situated in the wide S.W. portion of the loch. The maximum depth of 70 feet was observed to the north of Loch Craigs, considerably nearer the southern than the northern shore, and the slope of the bottom off Loch Craigs is evidently very steep, a sounding of 26 feet having been taken close to the shore."

The northern part, where the Melgam Water and the Inzion Burn enter, is shallow and obstructed by weeds, and there are no indications of a solid rock floor. Immediately east of Inzion there is a high bank of stratified yellow sands with occasional layers of boulders, and low down are some beds of fine clay free from stones. To the north are less conspicuous rounded banks of gravel, with a general east-west orientation, which present steeper slopes to the north than to the south. Beyond is the relatively flat stretch of Newton Moss. The Quharity Burn north of Newton farmhouse runs through alluvial flats with the hillocks of Muir Wood on the east and the gravel piles beyond Braes of Coul schoolhouse on the west. Still farther to the north, the Quharity occupies a typical transverse valley in the schists, meandering through flats much broader than its bed. Ignoring for the moment the accumulations of sand and gravel, we find ample evidence of the northward extension of the depression in which lies the Loch of Lintrathen.

I have examined the ground to the south of the loch and I can find no trace of an overflow in that direction although the Isla flows practically parallel to its southern margin less than half a mile away and in a gorge more than 200 feet below. For about 2 miles to the south there is rolling countryside with an average altitude of 500 feet, and beyond is a significant topographical feature. A conglomerate ridge, with a fairly uniform height of 900 feet above sea-level, which can be traced north-east from Blairgowrie for a distance of fully 6 miles, forming Glour o'er Him, Alyth Hill, Loyal Hill, and Barry Hill, loses its prominence, and south of the Loch of Lintrathen only a comparatively insignificant rise in the ground betokens its presence. The ridge reappears at Kinnaneil and can be traced along the north side of the Loch of Kinnordy, but it does not form so striking a feature as it does to the south-west. Immediately opposite the Loch of Lintrathen, at Brae of Shanzie, the ridge sinks to its minimum outside the Den of Airlie, and is below the 500 foot contour. This is indicative, in all probability, of the former southward continuation of the north-south valley at present partly occupied by the loch.

With regard to the antiquity of these transverse valleys in the schists, there appears to be no doubt that, from the occurrence of boulder clay in them, they are Pre-Glacial.[1] The peculiar configuration of the floor of the Loch of Lintrathen, with its maximum depth towards the south against the dacite outcrop, identifies it as a typical rock basin, excavated by a glacier occupying the transverse valley just described. To the north the schists probably stood up as a bold front to the Highland mass, from which there would be a correspondingly rapid descent of the glaciers to the more eroded, less steeply inclined, Old Red Sandstone surface, over which there would tend to be local thickening of the ice, such as is seen under present-day conditions in Arctic regions. After leaving the schists, the Lintrathen glacier met the Lower Old Red Sandstone strata on the north side of the syncline and so excavated its channel at first in the direction of dip. As the beds rose on the southern limb of the fold more difficulty would be experienced in the process of erosion, and this would be increased by the outcropping of the ledge of resistant dacite in its turn, a combination of obstacles which would result in local thickening of the ice with correspondingly greater erosion, as is evidenced in the common phenomena of " craig and tail " formation. This thickening, I suggest, took place between Balintore and Lintrathen with the result that, when the glacier did advance, the underlying conglomerate and dacite were excavated to form a rock basin.

---

[1] A. Geikie, *The Scenery of Scotland*, 3rd edition, 1901, p. 186. H. J. Mackinder, *Britain and the British Seas*, 1902, p. 127. P. Macnair, *The Geology and Scenery of the Grampians*, 1908, vol. i, p. 61; vol. ii, pp. 159–62. A. Scott, "Dry Channels in Glen Lednock," *Trans. Geol. Soc. Glasgow*, vol. xvi, 1916, p. 61.

According to this interpretation, the western portion of Newton Moss is simply the northern continuation of the glacier bed, and it is significant that if the boundaries of the depression are produced a few degrees east of north to Balintore a belt is obtained within which, on my 6 inch field maps, no record of rock in situ is to be found but immediately beyond which outcrops do occur. Newton Moss within this belt has a maximum altitude of approximately 735 feet, while to the east it falls to 725 feet. Less than 500 feet south-east of the right-angle bend of the Quharity Burn at Newton farm can be seen a flat truncating abruptly on either hand a ridge of basalt, obviously an old channel[1] leading into the slightly lower eastern part of Newton Moss, which is a conspicuously flat stretch with occasional relics of terraced margins—a lake floor. The levels of this floor and the present drainage from it indicate an easterly overflow through the deep cut by Auldallan (685 feet). To the east the channel falls to 650 feet, where it widens out into the lake flats with terraced margins, which stretch from Ascreavie Wood to Bridgend of Balloch, and finally to 570 feet in the Carity Den, the gorge cut through the outcrop of the dacite. This loch extended farther to the east beyond the outflow, for wide accumulations of sands and gravels continue to obscure the solid geology for the next half-mile, but it was limited to the south by the resistant dacite ridge. The channel described has a fall of 165 feet in 4 miles (1 : 128); the Melgam Water from the Loch of Lintrathen to Kinaird in a little over half-a-mile falls 60 feet (1 : 56).

---

[1] Following upon the cloudburst of 9th May, 1913, the Inzion Burn was unable to cope with the swollen waters of the Quharity, which discharged down the Carity causing serious flooding. There is a local legend that the mill-owners on the Carity used to bribe someone at Newton to divert periodically for their benefit the waters of the Quharity by means of a small drain.

For the water of the Lintrathen basin to follow the more northerly route by Auldallan, the present outlet at Bridgend of Lintrathen would require to be raised to 750 feet above sea-level, and the barrier continued southwards and westwards by Clint Law and Lochcraigs Wood to abut against the Knock of Formal. It would require to be continued also to the north-east by Gallow Knowe and Purgavie to the southern spur of Brankam Hill, making a barrier in all fully 3 miles long, blocking the passage of the streams from the Highlands down into Strathmore.

The most obvious agency which could produce such an obstacle is ice occupying Strathmore and encroaching upon the flanks of the Grampians. Positive evidence of the presence of ice in such a position is found in the roche moutonnée exposed on the south side of the farm road to Loanhead, about 700 feet due east of the south-east corner of the loch and 750 feet above sea-level. Its orientation is ten degrees north of east. The great pile of huge angular boulders of Lintrathen dacite found at the south-eastern end of the loch may represent the work of this ice-sheet.

To the west of this depression the valley of the Melgam Water rises from 680 feet at Inzion to approximately 780 feet at Dykend: to the east is the derelict drainage system by Auldallan to the Carity Den. The general easterly or north-easterly orientation of these channels suggests that the Strathmore ice thickened to the south-west and so at higher levels lay on the schist country, while to the east it thinned to a front somewhere near the Carity Den, where the melt water was able to reach lower levels towards the floor of Strathmore and flow to the sea by the Montrose Basin.

While the main erosion of the Auldallan channel would thus appear to be due to the marginal torrents of the Strathmore Glacier, its initial excavation was probably Pre-Glacial—by a tributary on the left bank of the precursor of the Quharity, working along the strike of the softer basalts and andesites between the Dalradian schistose grits and the Lower Old Red Sandstone conglomerates. That the last-named even then stood up as a N.E.–S.W. ridge is shown by the presence on north-east Kinclune Hill of a dry gorge, cut in conglomerate at an altitude of 1,050 feet and with a fall to the east, produced when the shrinkage of the Strathmore ice had revealed the top of the hill. With the continued thinning and retreat of this ice the melt water moved to the north where less than half a mile away the more easily eroded basalt offered a better channel along the margin of the upstanding schist-formed uplands. The preliminary trenching of the dacite outcrop at the Carity Den was due most probably to the transverse stream on the schists to the north, which was deflected later by glacial marginal drainage to the north-east—an hypothesis supported by the deflection of the 900 feet contour.

Having considered the drainage from the Loch of Lintrathen, there remains for our analysis the drainage into that basin. To the north there is the valley of the Quharity Burn, the size of which points unmistakably to much greater water supplies in the past, but as the glen is only some 3 miles long it seems difficult to account for the attenuation of the stream by climatic variation alone. Just below Longdrum, however, the hill ramparts to the west are breached and there is a conspicuous V-shaped notch with precipitous bare rock walls above and an accumulation of angular rock débris of often huge dimensions below—a waterfall or series of steep rapids serving as an overflow of a channel behind at an altitude of 1,084 feet. This is a somewhat sinuous dry valley known as Craig of Balloch, with fairly steep sides and a broad floor now occupied by a small peat moss, the drainage of which passes underground through a corrom, formed by a streamlet from the north, and reappears from below the piles of rock débris well down in the west side of the Quharity valley. The orientation of this high channel is roughly parallel to the strike of the schistose grits through which it is cut, but shows a curious disregard for a strong felsite dyke which it truncates twice. At its western end, the valley overlooks the transverse valley occupied by the Back Water, at a height of 170 feet above it. From the evidence of the present drainage in the Craig of Balloch channel and the " dry " waterfall at its eastern end, there can be no doubt that it carried an eastward-flowing stream of considerable size. As there is nothing on the west bank of the Back Water to correspond with this channel, the conclusion is inevitable that the Back Water itself once drained through the Craig of Balloch cut into the Quharity valley. For this to be possible the *lower* part of the Back Water transverse valley through the schists—of Pre-Glacial age—must have been blocked by a barrier 1,100 feet above sea-level. Here again the most readily comprehensible agency is a lobe of the Strathmore ice penetrating the lower portion of the Back Water valley. If it were sufficiently thick to extend up the valley of the Back Water, it is certain to have enveloped the Lintrathen basin as far north as Balintore (1,000 ft.), so that the marginal drainage from the Quharity channel probably passed eastwards by an earlier and higher Auldallan channel, more deeply excavated since. The western part of the Craig of Balloch channel may have been a Pre-Glacial tributary on the left bank of the Back Water, the notch behind the head of which determined the position of the overflow of the melt water into the adjacent Quharity valley, thereby reversing its drainage direction. The manner in which the felsite dyke has been cut through in two places suggests that at the time of its erosion it did not present any more resistant an obstacle than the adjacent schistose grits—possibly on account of the surface rocks being frozen, an explanation applied elsewhere to account for the cutting of "dry" valleys in Chalk and limestone country. The impotency of the present Quharity Burn is demonstrated by its inability to modify the contours which swing round to meet the outlet of the Craig of Balloch overflow.

The next overflow channel eastward from the Back Water (Melgam Water) is found below Pitewanhill Plantation where, at a height of approximately 920 feet, the south-west spur of Creigh Hill is truncated by a short, steep-sided gully, sloping gently eastwards, utilised when the Strathmore ice had shrunk to a little below the 1,000 feet contour. At the eastern end of the cut, the channel turns abruptly to the south-east, suggestive of a falling away of the ice front in that direction and probably indicative of an uncovering of the more northerly part of the Lintrathen basin. Hemmed in between the southern slopes of the Grampians to the north and the Strathmore ice edge about Inzion to the south, the melt waters were gathered into a lake, upon the floor and along the southern margin of which sands and gravels accumulated, while the outlet lay to the east through the Auldallan channel.

West of Dykend there is a striking dry valley known as Holm of Needs, with fairly steep sides and a broad flat floor, which is partly a peat-moss and partly a swamp. The channel is very nearly flat from end to end, but drainage to-day, which is to some extent artificial, is in an easterly direction, and in times of flood, melting snow, etc., the water always flows east. Half-way to its western end, the valley turns abruptly north-west, and then at the end from an altitude of 790 feet overlooks the Isla, 90 feet below. There is here a repetition of the field phenomena described in the case of the Craig of Balloch channel and the Back Water. The lower part of the Isla channel, a transverse Pre-Glacial valley in the schists, must have been blocked by Strathmore ice when its margin lay in the vicinity of the 1,000 feet contour, and the drainage of the upper Isla passed through the Holm of Needs, the Melgam channel, and so into the Lintrathen basin, the gradient being 1 : 120. It is difficult to believe that any part of the Holm of Needs is Pre-Glacial, it is so short a cutting between two pronounced transverse valleys. The initiation of the drainage there was influenced doubtless by the presence of a N.W.–S.E. fault-plane along which the channel has been excavated for more than half its length. The conspicuous north-east—south-west truncation of the 900 ft. contour on the north-west shoulder of the Knock of Formal, and the corresponding truncation of the 1,000 ft. contour on the south-east shoulder of Craiglea Hill to the north-west, together with the curious smooth "sky-line" between the two hills, are connected most probably with the blocking of the Isla and the passage of a lobe of the Strathmore ice over the ridge to Pitewan.

The succeeding stage in the retreat of the ice revealed the Melgam Water valley, which in the area Dykend, Pitewan, Nether Scithie, forms a broad alluvial flat at an altitude of about 780 feet. It is possible that this old lake represents the remains of a rock basin excavated by the glacier which earlier occupied the valley of the Back Water. As in the case of the Loch of Lintrathen, the southern margin of the depression is formed by the dacite outcrop, but, as this time it is on the northern limb of the syncline, erosion took place in the direction of dip, or nearly so, with the result that there is no ridge feature corresponding to that seen along the south shore at Lintrathen. Between the alluvial flats and the Loch of Lintrathen, the Melgam Water occupies a channel larger than is attributable to the present stream, with occasional relics of terraces. With the uncovering of the lower Lintrathen basin, the centre of accumulation of melt water moved south, probably on account of the general raising of the level over the Newton Moss area by the spread of sands and gravels to which reference has been made already. The new loch, impounded between stretches of superficial deposits on the north and the dacite ridge to the south, found an outlet to the south-east along the strike of the more easily eroded basalts and tuffs between the dacite and the conglomerates, and circumvented the acid lava flow in the manner described earlier.

The latest stage in the retreat of the Strathmore ice to the south-west, with which it is proposed to deal in this paper, was when the north-west margin south of Lintrathen lay near the 400 ft. contour, and the present Isla drainage system came into operation. South of the Holm of Needs overflow, the Isla occupies its old channel, which is broad and has gently sloping sides. Below Fornethy it meanders through a broad alluvial flat in which a recent excavation showed 24 feet of boulder clay without reaching bed-rock. Downstream the flat opens out and has terraced margins, the highest one being about 40 feet above the present river level. It is interesting to note that this old loch lies on the line of the transverse Pre-Glacial valley and has been excavated where the resistant dacite outcrop rises along the southern limb of the shallow syncline, so that there is a striking resemblance in point of view of structure, position and origin, between the Loch of Lintrathen, " Pitewan " Loch, and the loch at Milna Craig.

Below Milna Craig, the Isla plunges over the Reekie Linn, having excavated what is more or less a strike section, a long, narrow, and in places tortuous gorge, with walls a hundred feet in height, from which it emerges 4 miles downstream at Dillavaird Bridge, the gradient being 1 : 60. This figure compares very closely with that for the Melgam Water below the Loch of Lintrathen—1 : 56, and it is in marked contrast with the gradient (1 : 125) of the marginal drainage channels forced by the Strathmore ice to " follow the contours ".

To sum up, it is contended that the major transverse (north-west—south-east) valleys in the Dalradian Schists represent the channels of Pre-Glacial streams, occupied during early Glacial times by Highland Glaciers which excavated rock basins mainly against the resistant dacite lava outcrop. After the retreat of these glaciers, the Strathmore Glacier advanced north-eastward *up* Strathmore and encroached upon the fringe of the Grampians on its north-west flank. During the retreat of this ice to the south-west, the marginal drainage was forced to flow to the north-east, along the contours of the hills, eroding deeply old channels and cutting new ones. The continued retreat of this ice uncovered the rock basins, which became lakes, and permitted their drainage to re-enter the lower parts of the strath, the topography of which had been so profoundly modified during the interval that new channels had to be excavated. As has been pointed out by Dr. R. Campbell,[1] the depth to which glacial erosion extended in Strathmore must have been very considerable to yield the red boulder clay, full of fragments of the Strathmore sandstones and marls, which covers so wide an area in Kincardineshire and spread into Aberdeenshire. Professor R. S. Tarr has suggested that the measure of glacial erosion in the Scottish Highlands is hundreds of feet and in places perhaps a thousand feet.[2] It is interesting to note that the oscillation of glaciers required by this hypothesis corresponds closely with that postulated by Dr. A. Bremner to explain the succession of deposits at the Bay of Nigg, Aberdeen.[3]

There is no evidence that the gorges, which characterise the lower parts of the streams from the Highlands, were in existence in Pre-Glacial times. They contain no boulder-clay and are devoid of any trace of ice-moulding or sculpturing such as one would have expected to occur along their upper margins. Their extremely tortuous courses, often with right-angle bends very close together, practically preclude the possibility of ice moving along them. Unless the glacier moving down the Quharity valley to Lintrathen excavated a new channel to the south of the loch basin through a rock barrier some 300 feet high, which seems distinctly improbable, the Pre-Glacial valley ran almost due south *across the course of the present Isla gorge*, which runs a little south of east, less than half a mile to the south of the loch, and nearly 250 feet below. This crossing at what is almost a right-angle is certainly significant. It may be suggested that the Pre-Glacial valley turned abruptly to the east immediately south of the dacite outcrop, but a stream flowing from the Highlands would be deflected surely on the upstream side of the resistant ledge, not the downstream one.

The winding Isla gorge I am inclined to regard, therefore, as a sinuous channel eroded since the south-westward retreat of the Strathmore Glacier, which had excavated the soft marls and sandstones of Strathmore to such an extent that the canyons have

---

[1] Thomson Memorial Lectures delivered at Aberdeen in 1926 (unpublished).

[2] "Glacial Erosion in the Scottish Highlands," *Scot. Geographical Mag.*, vol. xxiv, 1908, p. 586.

[3] "Further Problems in the Glacial Geology of North-eastern Scotland," *Trans. Geol. Soc. Edin.*, vol. xii, 1928, p. 147.

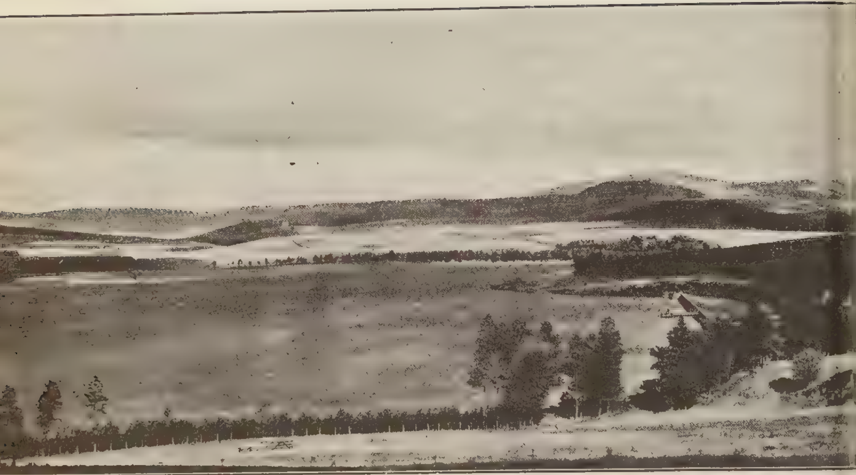


FIG. 1. THE LOCH OF LINTRATHEN FROM THE S.E.

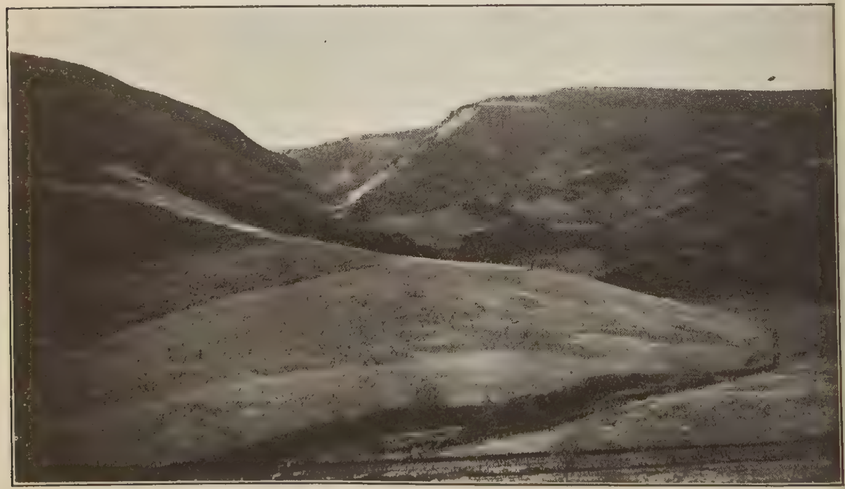


FIG. 2.—EASTERN END OF BALLOCH CHANNEL.

To face p. 39.]

been cut downward and backward in the higher ground along the north-west margin of the strath by ordinary fluviatile erosion, a process which was rendered additionally effective by the uplift evidenced by the Raised Beaches. Nor is there any incompatibility between the consequent youth of the gorge and its noteworthy depth, in spite of the comparatively slow erosion observed at the present time. All the gorges of the area reflect the abundance of melt water available from the hilly country to the north-west, and their steep walls the corresponding rapidity with which they were cut, the ordinary processes of denudation being unable to keep pace with the major excavation and so grade down the sides. While no detailed analysis of the development of the drainage systems of this part of the Highlands has been published hitherto, references to the Isla gorge are to be found in the late Sir Archibald Geikie's *The Scenery of Scotland*,[1] where he advances the contention that many of the gorges are of comparatively recent origin, and instances among others the 80 feet deep channel of the Water of Gregg in Ayrshire, with its Pre-Glacial course, 100 feet deep, obliterated by boulder clay, exposed in the immediate vicinity. The absence of similar evidence of the post-Strathmore Glacier origin of the Isla gorge is to be ascribed to the Strathmore ice erosion which made the channel excavation inevitable.

I am greatly indebted to Mr. George Baxter, Jun., A.M.I.C.E., General Manager and Chief Engineer of the Dundee Corporation Waterworks, for the privilege of inspecting the working plans of the Waterworks at Lintrathen, for permission to include a photograph (Plate I, Fig. 1) which is the property of the Department, and for his kindness in searching the records for information for me.

EXPLANATION OF PLATES I–III.

Plate I.

Fig. 1.—The Loch of Lintrathen with its overflow across the dam at the south-east corner. In the foreground is the dacite ridge, and the headland to the right beyond the dam is formed of the overlying basalts and conglomerates. The tree-clad bank on the farther shore to the left consists of bedded sands and gravels, behind which is Newton Moss. The Auldallan channel lies in the hollow between Balintore Castle, seen in the middle background, and the light-coloured hill slope in front. The Quharity Burn flows down the valley to the left of Balintore Castle.

Fig. 2.—The east end of the Craig of Balloch channel showing the V-shaped notch in the Dalradian Schists, flanked by screes, down which the melt waters passed to the Quharity "transverse valley" leading to the Lintrathen Basin. In the foreground is a delta of detritus, thrown down by the earlier floods, which served as a barrier against the diminished volume of water in the later stages of the employment of the cross-channel and deflected the currents *up* the Quharity valley for a short distance.

---

[1] Loc. cit. supra, 3rd edition, 1901, pp. 379, 396, etc.

PLATE II.

The east end of the Auldallan channel occupied by the diminutive Carity Burn, just above the point of its debouchment on to the wide alluvial flats between Ascreavie and the dacite barrier at Carity Den. The bank to the left is composed of Lower Old Red Sandstone lavas and conglomerates, that to the right of Dalradian Schists. The gently sloping sides and the broad flat gravel-strewn floor are conspicuous features.

PLATE III.

The River Isla gorge cut through Lower Old Red Sandstone andesite lava flows below the Reekie Linn, Milna Craig. The walls, fully a hundred feet in height, are almost perpendicular, and the river occupies practically the whole width of the rocky floor.

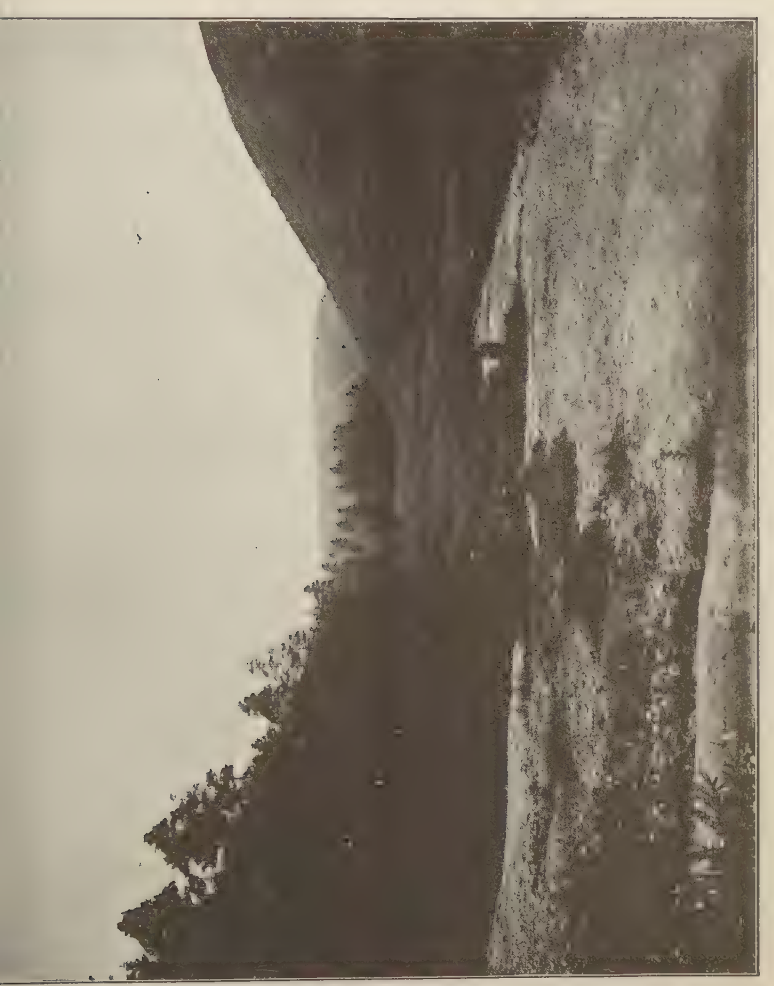
An Igneous Conglomerate at Woolley, Devon.

By A. W. GROVES, M.Sc., D.I.C., Research Student, Royal College of Science, London.

ON Sheet 339 of the One Inch (New Series) Map of the Geological Survey there is marked at Woolley, within the metamorphic aureole of the Dartmoor granite, between Bovey Tracey and Lustleigh, a patch of " Permian " rocks. Upon inquiry the Director of the Geological Survey, Sir John Flett, informed me that this was an error and should have been marked as " Felsite ". As the rock constituting the outcrop presents unusual features and is very different from an ordinary felsite I feel that a description of it should be placed on record. Moreover, it appears to be a good example of a rather uncommon rock type.

It occurs between the Carboniferous rocks and the granite proper. In the field it has the appearance of a coarse conglomerate invaded by granitic fluids. The outcrop is largely obscured by drift, but blocks of it occur in the fields and it is actually exposed in a few places in the sunken lanes. At its furthest point from the granite the matrix has weathered and is decomposed so that the contained pebbles may be pulled out. Three possibilities at once suggest themselves; either it is a Carboniferous conglomerate contact metamorphosed and drenched with granitic material, or a Permian breccia similarly altered, or an igneous conglomerate formed of marginal facies of the granite. It turns out to be the latter with the probable addition of tourmalinized fragments of country rock.

Examination of a number of boulders and a suite of thin sections shows that the rock consists of rounded pebbles of the following (given in the relative order of abundance):—Quartz-tourmaline, tourmalinized rock, vein quartz, rounded orthoclase crystals, black schorl, together with some unrecognizable types. Among the last mentioned are some pebbles with aggregates of acicular rutile, accompanied by a little biotite and set in a quartz groundmass in optical continuity with the quartz of the matrix of the conglomerate. Quartz-tourmaline pebbles occur up to 6 or 8 inches in



Eastern End of Auldallan Channel.

[*To face p. 40.*

RIVER ISLA, GORGE BELOW THE REEKIE LINN.

length. Pebbles of the other materials rarely exceed 2 inches, and the sizes of all the types of pebbles grade downwards into fragments of a few millimetres. Between the larger fragments is a matrix of angular quartz grains containing myriads of minute gas or liquid bubbles together with opaque inclusions. This is in turn invaded and cemented by a cryptocrystalline groundmass of a pale cream colour. Between crossed nicols this fine-grained groundmass shows an occasional tendency to brush polarization, and this together with the fact that felspar appears to be absent, and that the refractive index is slightly lower than that of the Canada balsam, seems to indicate that this cementing material is chalcedonic rather than felsitic. Some of the quartz grains are slightly crenulated by the chalcedonic groundmass. Frequently the chalcedonic groundmass gives way to another composed of quartz and acicular tourmaline (of blue and indigo shades) simulating "luxullianite". Minute crystals of acicular tourmaline are also visible under the high power in the chalcedonic groundmass. In addition to the quartz grains of the matrix there are rare grains of felspar showing twin lamellation, which are probably oligoclase. Several zoned Dartmoor zircons were observed in the groundmass together with some rare rutile.

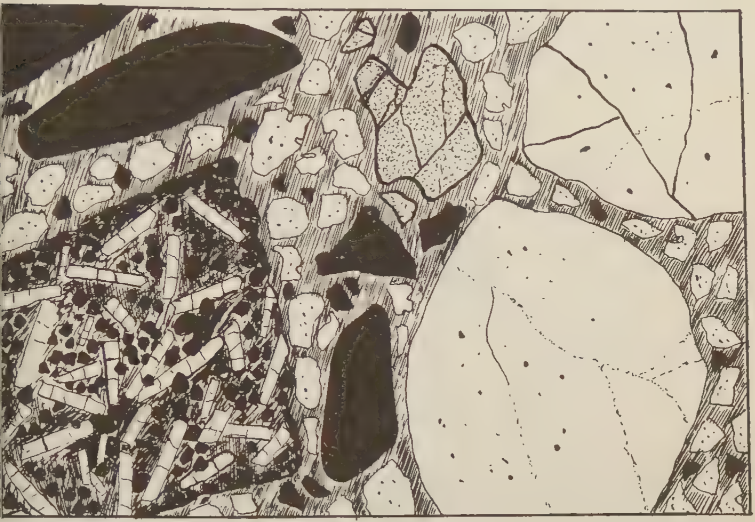


FIG. 1.—Igneous conglomerate, Woolley, Devon. × 7. Pebbles of schorl, matted acicular tourmaline, and quartz are seen embedded in a matrix of angular, sometimes crenulated, quartz grains cemented by a cryptocrystalline, probably chalcedonic, groundmass. Blue tourmaline and schorl are also developed in the groundmass.

In a clean-cut exposure by the cottage near the railway bridge at Woolley the matrix of the rock has been weathered and is so decomposed that the pebbles may be pulled out by hand. A sample of this decomposed matrix was passed through bromoform and the great bulk of the residue was found to consist of tourmaline. The non-magnetic portion consists largely of zoned Dartmoor zircons together with smaller quantities of the clear Dartmoor-type zircons, biotite, anatase, and cassiterite.

The pebbles described as tourmalinized rock merit further description. They consist of a closely matted mass of small acicular crystals of blue to green tourmaline orientated in all directions. The only other mineral occurring in them is a varying amount of interstitial quartz. The outline of these pebbles may be either well rounded or sharply angular, and in the hand specimen they are black. These do not appear to be derived from ordinary quartz-tourmaline veins but are suggestive of intensely tourmalinized fragments of shale or basic rock, although, if such, all traces of former structure have been obliterated. The boundaries of the intensely tourmalinized pebbles are absolutely sharp, but the quartz of some of the quartz-tourmaline pebbles is optically continuous with the quartz of the matrix of the conglomerate when this is of the "luxullianite" type.

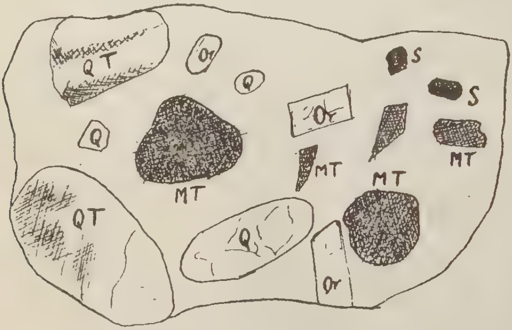


Fig. 2.—Hand specimen of the conglomerate ($\times \frac{1}{3}$), showing mode of occurrence of pebbles of quartz-tourmaline (QT), matted tourmaline (MT), quartz (Q), orthoclase (Or.), and schorl (S.).

To sum up, the rock consists of igneous fragments and possibly altered contact metamorphic types, all intimately connected with the Dartmoor granite, set in a quartz-tourmaline and chalcedonic matrix, and constitutes an igneous conglomerate at the margin of the granite. A peculiar feature of this rock is the almost complete absence of biotite, the ferro-magnesians and alkalis having all been used in the formation of tourmaline. The cementing material would probably have been felsitic had it not been for the presence of abundant boric acid fluxes promoting a strong tendency towards the formation of tourmaline. A somewhat similar rock is the "igneous breccia" of Sederholm,[1] but in the occurrence at Woolley the larger pebbles are well rounded while the smaller ones are often sharply angular. A list of intrusion breccias in other parts of the British Isles is given by Professor S. H. Reynolds in his recent paper on breccias.[2]

REVIEWS.

Der Bewegungsmechanismus der Erde. By R. Staub. pp. viii + 270, with coloured map and 44 text-figures. Berlin: Gebrüder Borntraeger, 1928. Price 18 marks, bound 20·50 marks.

EVERY science passes through periods of analysis and observation alternating, more or less definitely, with periods of synthesis and theory, just as, in the history of the earth, periods of quiescence alternate with periods of mountain-building. In geology a long period of analysis has produced a peneplain of fragmental material with a few monadnocks, such as the contraction theory, which remain from the past and have resisted the most violent efforts to reduce them to the common level. But now we seem to be entering a period of theory-building. Within the last few years a number of works have appeared which deal with the broader aspects of the science and try to explain the whole structure of the globe. Dr. Staub's book is one of them and, whether he is right or wrong in his conclusions, it is one of the best. It is the work of a geologist who is familiar with tectonics and will not attribute the island arcs of Asia to tension or otherwise offend the geological conscience.

Staub follows Wegener in assuming that the continental masses float in a denser magma and that a force, which he calls centrifugal,[3] drives them towards the equator. But he does not suppose that the Americas have drifted away from the Old World, and for him the Pacific floor has always been a rigid area quite as resistant as the continents themselves.

His views have been evolved in an endeavour to trace the Alpine System of folds throughout the world, and here he differs from most previous writers. According to him the orogenic zone of western North America does not curve through the arc of the Lesser Antilles into the Andes. It passes through the Greater Antilles and continues eastward across the Atlantic to unite with the Alpine System of Europe. Similarly the Andean folds turn eastward through

---

[1] "Om granit och gneiss," *Bull. Comm. Geol. Finland*, p. 23, 1907.

[2] Geol. Mag., Vol. LXIV, 1928, pp. 103–104.

[3] The term is not altogether appropriate and may mislead. Perhaps the simplest and most readily accessible discussion of the forces in question is that by W. D. Lambert in *Amer. Journ. of Sci.*, 1921, vol. ii, p. 129.

Trinidad to join the Moroccan Atlas. It has long been recognized that all the principal folding of the West Indies trends from west to east, and grave doubt has been cast upon the idea that the Lesser Antilles form a linking curve between the folded zones of North and South America.

The general conception of the Alpine System which Staub reaches gives a figure not unlike a *Tetragraptus*. There is a central belt of folding which runs from west to east, and at each extremity the belt divides into a northern and a southern branch bordering the Pacific. This conception leads naturally to his general theory. There is a Pacific rigid block which maintains its position. There is a northern continental mass which he calls Laurasia and a southern continental mass which he calls Gondwana. Between them a geosyncline was formed, and as the two masses moved towards the equator the compression of the geosyncline gave rise to the central mountain belt. Upon the eastern and western margins of the two masses there was crushing against the Pacific block, and accordingly on east and west the central belt divides and the branches pass along the outer margins of Laurasia and Gondwana.

But Staub goes further than this and tries to explain on the same general principles the formation of the earlier mountain systems. If both northern and southern masses try to centre themselves upon the equator it is possible that, after they have met, one of them may drive the other before it, but, since both are rigid, there can be no more folding and mountain-building will cease. Staub imagines that now another force comes into play. While the masses approach each other and the roots of the intervening mountain belt are forced downwards, there must be displacement of the magma and under-currents will flow towards the poles. The equatorward force diminishes from 45° lat. to the equator, and Staub's idea is that as the masses approach the equator there will at length come a time when this force will be overpowered by the drag of the poleward magmatic currents. The masses will then separate and move back towards the poles. A belt of weakness will be produced between them and a new geosyncline formed which will ultimately give rise to a new mountain system.

In assuming that the Pacific area is a rigid block, Staub is adopting a view that has been held, and more or less clearly expressed, by several geologists. The idea was present in the mind of Suess and it led Haug to insert a hypothetical Pacific continent in his palaeogeographical maps. But a rigid area is not necessarily continental. Staub supposes that the Pacific block consists of basic rock, and he connects its formation with Sir G. Darwin's suggestion that the Pacific depression marks the place where the moon separated from the earth. He thinks that the disturbance might lead to rapid and deep consolidation of the magma.

A serious objection to Staub's theory is the inadequacy of the forces to produce the required effects. The equatorward force is at its maximum 45° away from the equator and diminishes to zero at the poles and the equator. Even at 45° it is only equal to about 1/2,000,000th part of gravity, and this force has to push the continents through the magma, produce magmatic currents, and lift the floor of the geosyncline to Alpine and Himalayan heights against the force of gravity. Even Wegener allows that it is doubtful whether it is sufficient to account for the elevation of the central mountain ranges.

There seems to be no reason why the poleward force imagined by Staub should ever exceed the equatorward force. The poleward force is due to the magmatic currents, which are themselves the consequence of the movements due to the equatorward force. If the poleward force ever equals the equatorward force the movement will stop, the equatorward force will cease to diminish, and the poleward force to increase.

A geometrical difficulty, which Staub does not sufficiently consider, arises from the fact that the earth is not built on Mercator's or any other cylindrical projection. There is not room upon the globe for Staub's Laurasia to move more than a very short distance towards the pole. The two sides would come together and it would jam.

Although the mechanism suggested by Staub is not convincing, there is much in his ideas of the structure of the earth that is worth careful consideration, and his book is a valuable contribution to the tectonics of the globe.

P. L.

British Floods and Droughts. By C. E. P. Brooks and J. Glasspoole. pp. 199, with 2 plates and 15 text-figs. London: Ernest Benn, Ltd. 1928. Price 10*s*. 6*d*.

ALTHOUGH it may perhaps be considered that British geologists are concerned with the modern weather mainly as an incentive or a deterrent to active field work, nevertheless this comprehensive study does give food for reflection as regards its bearing on the conditions of past times. It is sufficiently remarkable that in an area so small as England it should be possible to record annual rainfalls varying from 10 inches at Margate in 1921 to 247 inches at the Sty Head Pass in Cumberland in 1923. Again, the effects of concentrated rainfall (cloudbursts) may throw light on wash-outs among ancient strata. Such a downpour as that of nearly 10 inches in a day, recorded at Bruton, Somerset, in 1917, could not fail to produce some record among sedimentary deposits formed by the rivers draining the area. On the other hand, the effects of droughts are likely to be less conspicuous in the geological record. In this connection it is perhaps worth noting that what the mainly suburban but highly vocal population of south-eastern England regards as a disastrous drought, such as the summer of 1921, is in reality an unmixed blessing to the agricultural community of a large part of these islands, affording excellent hay and corn harvests in areas where in " normal " summers the farmer is kept in a state of constant agitation by the vagaries of the weather and the prospects of his crops.

THE GENESIS OF ALKALINE ROCKS. By C. H. SMYTH, JUN. Reprinted from the Bicentenary Number of the American Philosophical Society's Proceedings, vol. lxvi, 1927, pp. 535–80.

SOME fifteen years ago the author of this interesting and comprehensive paper set forth his idea that the origin of the alkaline rocks is indicated by their relatively high content of mineralizers and of rare elements. This theory is now amplified and brought up to date in relation to much original work that has since appeared. The concentration of fluxes and rare elements is attributed to slow and undisturbed cooling in stable regions, dominated by vertical rather than tangential stresses, allowing of a very complete separation of the magmatic constituents, in contrast to the rapid injections of only partially differentiated magmas in regions of tangential pressure. With particular reference to the ideas of Daly and Brögger as to assimilation of limestone as a genetic factor, it is contended that alkaline magmas did not arise as a consequence of this process, but that such assimilation was rendered possible by the special characteristics of the magmas already differentiated by other means. In support of this thesis a great number of the alkaline rock occurrences of the world are cited: Harker's generalization of the association of alkaline and calc-alkaline rocks with vertical and horizontal crust-movements respectively is well supported, though regarded as an effect rather than a cause, whereas the assimilation of vast masses of limestone receives scant sympathy. This important paper should be read with care by all petrologists, since it affords an excellent summary of the present state of knowledge concerning the alkaline rocks.

R. H. R.

A SERIES OF ELEMENTARY EXERCISES UPON GEOLOGICAL MAPS. By JOHN I. PLATT, M.Sc., F.G.S. Published by Murby and Co. Price 1*s.* 6*d.*

MR. PLATT and Messrs. Murby deserve the thanks of all teachers of geological map reading for the collection and publication of this most useful set of maps at so reasonable a price. One or two are perhaps rather obviously " constructed " rather than " mapped ", for example in Map 15 one would have expected the Ordovician to show some effect of the tilting given to the Carboniferous, but apart from this the collection will be found most suitable for elementary classes, and it is an added advantage to the teacher that sets of any one map are procurable from the publishers at a similar small cost.

G. L. E.

REPORTS AND PROCEEDINGS.

GLASGOW GEOLOGICAL SOCIETY.

11*th October*, 1928.

Presidential Address: "Scottish Carboniferous Stratigraphy." Part II. By M. Macgregor, M.A., B.Sc., Assistant Director H.M. Geological Survey.

In the first part of this address (GEOL. MAG., Vol. LXV, p. 45) the Scottish Carboniferous succession down to the base of the Carboniferous Limestone Series was dealt with and the variations in lithological facies and thickness shown by each subdivision briefly traced. Part II deals first with the advances made towards correlation of the worked and workable coals in the two productive subdivisions, the Limestone Coal Group and the Productive Coal Measures. The importance of securing as detailed and exact criteria as possible for correlation between different parts of a coalfield or between different coalfields was emphasized and attention drawn to the value of correlation tables as a basis for a complete survey of our coal resources and of the physical and chemical properties of individual seams. Tables showing the extent to which correlation of the chief coals can be carried with the information at present available were shown, and the criteria made use of in constructing these were pointed out. The factors tending to limit detailed inter-coalfield comparison were discussed, the most important of these being the great variation in character and amount of sedimentation in the different areas. These variations indicate different crustal movement over the Scottish region of deposition and suggest that throughout Calciferous Sandstone times certain parts of this region were relatively stable. An examination of the Calciferous Sandstone rocks was then undertaken, and their characteristic development in different areas of the Scottish Lowlands described. The lagoonal phase of the Cementstone Group was followed by an outburst of igneous activity which built up great piles of subaerial volcanic rocks (Clyde Plateau Lavas, Garleton Hills, etc.), and this in turn by a prolonged period of denudation. At the same time sedimentation was going on continuously, or almost continuously, in certain areas (e.g. East Fife, West and Mid-Lothian), and the break-up of the old land masses of lavas and older rocks appears to have been due to the formation of gulfs by which the area of sedimentation was gradually extended. The higher Calciferous Sandstone sediments overlapped on to the old land areas; then followed subsidence which carried the greater part of the region down into the Lower Limestone sea. During this subsidence, however, the barriers of rock separating the basins and gulfs of late Calciferous Sandstone times persisted as relatively more stable areas, and it is in the neighbourhood of these that sedimentation throughout succeeding periods was least.

CORRESPONDENCE.

PIPES IN COAST SANDSTONES.

Sir,—It is interesting to note in connection with Professor Day's paper on "Pipes in the Coast Sandstone of Syria", published in your September number, that pipes agreeing in a remarkable manner with those described by him are present in a Pleistocene sandstone on the north shore of Barnstaple Bay in Devonshire, between Saunton and Downend. Here a calcareous sandstone overlies the well known 15 ft. raised beach and is unconformable to the Pilton Beds of the Upper Devonian. This sandstone, which is water-deposited at the base but aeolian above, contains many vertical pipes which are apparently identical with those in the Syrian sandstone. The only different feature seems to be that, as the sea has excavated a number of small caves along the unconformable junction between the sandstone and the Pilton Beds, every pipe which has pierced the roof of a cave forms an open chimney through which it is possible to climb.

These Devonshire pipes do not seem to be as well known as they deserve to be, although they have been described in detail in various papers published many years ago in the *Transactions of the Devonshire Association*, notably by Mr. W. Pengelly, F.R.S., and Mr. J. G. Hamling. As far as I can remember, the conclusion arrived at by these authors was that the pipes were caused by solution, but, like Professor Day, they also found the general regularity and smoothness of the walls difficult to explain by this theory alone.

I hope that Professor Day's communication will have the result of bringing these remarkable Devonshire pipes out of their obscurity.

N. L. Falcon.

Masjid-i-Sulaiman,
South Persia.
18*th October,* 1928.

BACK NUMBERS OF THE *GEOLOGICAL MAGAZINE.*

Sir,—The Library of the University of Witwatersrand has lost its copy of the Geological Magazine for January, 1926, and January, 1927. Both numbers are out of print, and Mr. S. B. Asher, the Librarian, has asked me if I could help him in replacing these copies. If any readers of the Magazine should be able to spare these numbers it would be very helpful if they would send them either to me or forward them direct to Mr. S. B. Asher, Seymour Memorial Library, Kerk Street, Johannesburg.

Yours faithfully,
J. W. Gregory.